T.C. Memo. 2009-50

UNITED STATES TAX COURT

UNION CARBIDE CORPORATION AND SUBSIDIARIES, Petitioner v. COMMISSIONER OF INTERNAL REVENUE, Respondent

Docket No. 11119-99. Filed March 10, 2009.

R determined deficiencies in P's Federal income tax for 1994 and 1995. Pursuant to a negotiated agreement, P was allowed research credits under sec. 41, I.R.C., for 1994 and 1995. In an amended petition P now seeks additional research credits for 106 projects conducted at its manufacturing plants. To resolve this action expeditiously, P and R agreed to try five of the largest projects underlying P's research credit claim.

Held: Two of the five projects constitute qualified research under sec. 41(d), I.R.C.

Held, further, P has established that it included all activities that were similar to the two qualified research projects in its calculation of its base amount under sec. 41(c)(4), I.R.C.

Held, further, P has established that it incurred $1,045 of additional qualified research expenditures

(QREs) for wages paid to specific plant employees for qualified services performed during the two qualified research projects. The remaining expenditures for which P claims additional research credits are not QREs because they were incurred in the production of goods for sale, not in the conduct of qualified research.

Held, further, P improperly included production costs in its base amount. However, because P's error caused P to overestimate its base amount, we find P's error to be harmless and accept P's calculation of its additional base period QREs with several adjustments.

Harold J. Heltzer, Alex E. Sadler, Robert L. Willmore, Peter B. Work, and Allen D. Madison, for petitioner.

Jill A. Frisch, Daniel A. Rosen, Lyle B. Press, Alex Shlivko, and Jenny D. Boissonneault, for respondent.

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MEMORANDUM FINDINGS OF FACT AND OPINION

GOEKE, Judge: Respondent determined deficiencies in petitioner's Federal income tax of $20,481,520 and $140,732,254 for 1994 and 1995, respectively. In its petition, as amended,

petitioner alleges that it is entitled to additional research credits under section 41[1] of approximately $3,656,091 and $4,726,664 for 1994 and 1995, respectively (claimed credits).[2] The claimed credits are based on 106 projects it conducted in various units within six manufacturing plants during 1994 and 1995 (credit years). For purposes of resolving this action expeditiously, the parties have agreed to try five of the largest projects[3] underlying petitioner's affirmative research credit claims (claim projects).[4]

The issue before the Court is whether petitioner is entitled to additional research credits under section 41 for 1994 or 1995.[5] Resolution of this issue requires us to determine: (1)

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[1]Unless otherwise indicated, all section references are to the Internal Revenue Code in effect for the years at issue, and all Rule references are to the Tax Court Rules of Practice and Procedure.

[2]In its original petition, petitioner claimed as affirmative adjustments additional research credits of $4,808,671 and $5,851,619 for 1994 and 1995, respectively.

After amending its petition, petitioner has conceded that an additional project does not satisfy the requirements of sec. 41(d). This concession does not affect our discussion of petitioner's claims and will be addressed in the parties' Rule 155 computations.

[3]The term "projects" is used for convenience.

[4]Petitioner withdrew a sixth project before trial.

[5]All other issues in this case were resolved by agreement of the parties or our previous Opinion in Union Carbide Foreign Sales Corp. v. Commissioner, 115 T.C. 423 (2000).

Whether any of the claim projects constitute qualified research under section 41(d); (2) whether any of the claim projects constitute qualified research, whether petitioner included all activities that were similar to the claim projects in its calculation of its base amount under section 41(c)(4); (3) if any of the claim projects constitute qualified research under section 41(d), whether the claimed costs of supplies and wages attributable to those projects (claimed costs) are qualified research expenditures under section 41(b) (QREs); and (4) if any of the claimed costs are QREs, whether petitioner included all similar costs in its base amount calculation.

FINDINGS OF FACT

I. Overview

Some of the facts have been stipulated and are so found. The stipulated facts and the accompanying exhibits are incorporated herein by this reference.

A. Petitioner

Union Carbide Corp. (UCC) was the parent corporation of a group of corporations (collectively, petitioner) that filed consolidated Federal income tax returns for the years ending December 31, 1994 and 1995. UCC is a corporation organized and existing under the laws of the State of New York. At the time the petition was filed, UCC maintained its principal corporate office in Danbury, Connecticut.

At all relevant times petitioner was a worldwide manufacturer and marketer of basic chemicals and plastics and specialty and intermediate chemicals. Petitioner conducted its operations at large-scale production facilities throughout the United States and abroad.

Petitioner's basic chemicals and plastics (C&P) operations involved the processing of raw hydrocarbon feedstocks--principally ethane, propane, and naphtha--into basic building-block chemicals known as olefins. Ethylene and propylene were the major olefins UCC produced and were key raw materials for petitioner's olefins-chain C&P businesses.

Petitioner used process technologies to convert manufactured and purchased ethylene and polypropylene into first-line derivatives such as: (1) Polyethylene, which is used for high-volume applications such as food containers, milk and water bottles, grocery and trash bags, pipes, and tubing; (2) polypropylene, which is used for similar high-volume applications; and (3) ethylene oxide/glycol and derivatives, which are used for products such as automobile antifreeze, polyester resin, and film and as raw materials for petitioner's specialty and intermediates chemicals business.

Petitioner's specialty and intermediates chemicals operations involved the production of a wide variety of specialty chemical and polymer product lines, as well as solvents and

chemical intermediates. During the credit years petitioner also licensed its key olefins-based process technologies, such as the UNIPOL process for manufacturing polyethylene, to third parties in the oil and gas petrochemical industries.

During the credit years UCC maintained research and development (R&D) technical centers in South Charleston, West Virginia (South Charleston); Tarrytown, New York; Bound Brook, Edison, and Somerset, New Jersey; and Cary, North Carolina. UCC carried out process and design engineering at the technical center in South Charleston.

On February 6, 2001, UCC merged into a wholly owned subsidiary of Dow Chemical Co. (Dow).

B. Procedural History

UCC, as the common parent of petitioner's consolidated group, timely filed consolidated Federal income tax returns for the years at issue on Forms 1120, U.S. Corporation Income Tax Return.

On its 1994 and 1995 Federal income tax returns (returns), petitioner claimed research credits of $14,100,887 and $4,053,901 for 1994 and 1995, respectively (original returns research credits). UCC elected the reduced research credit under section 280C(c)(3) on its 1995 return, but not on its 1994 return.

In computing the original returns research credits, petitioner included the following amounts as QREs for 1984

through 1988 attributable to UCC (UCC's original returns base period QREs):

Year	UCC's Original Returns Base Period QREs
1984	$68,503,722
1985	64,742,828
1986	48,107,169
1987	52,170,492
1988	70,499,622
Total	304,023,833

UCC's original returns base period QREs for 1984 through 1987 were drawn exclusively from UCC's R&D technical centers. UCC's 1988 original returns base period QREs were drawn from UCC's R&D technical centers except for $1.9 million attributable to UCC's G-1750 reactor at its Seadrift facility in Texas (Seadrift).

UCC's annual gross receipts for the base period were as follows:

Year	UCC's Annual Gross Receipts
1984	$2,737,545,150
1985	2,440,721,126
1986	2,976,592,778
1987	3,547,163,938
1988	5,033,745,128
Total	16,735,768,120

UCC's annual gross receipts for 1990 through 1994 were as follows:

Year	UCC's Annual Gross Receipts
1990	$4,010,083,913
1991	3,724,913,910
1992	3,608,486,054
1993	3,617,655,799
1994	3,789,545,361

On March 22, 1999, respondent timely mailed a notice of deficiency to petitioner determining income tax deficiencies of $20,481,520 and $140,732,254 for 1994 and 1995, respectively.

The parties negotiated an agreement that resolved most of the issues raised in the notice of deficiency. Respondent allowed petitioner's original returns research credits as part of the negotiated agreement.

Petitioner alleges in its petition, as amended, that it is entitled to additional claimed credits of approximately $3,656,091 and $4,726,664 for 1994 and 1995, respectively.[6] Petitioner's claimed credits are based on 106 projects it conducted in various units within six manufacturing plants during the claim years.

[6]These figures have not been adjusted to reflect the fact that petitioner has conceded that some of the projects do not satisfy the requirements of sec. 41(d).

In computing the claimed credits, petitioner claimed $56,247,556 and $145,435,822 as additional QREs under section 41(b) for 1994 and 1995, respectively (claimed QREs). The amount of claimed QREs for 1995 is the full-year amount although petitioner acknowledges that section 41 does not apply to any amount paid or incurred after June 30, 1995, and before January 1, 1996, and petitioner will disregard such amounts in computing the amount of additional research credits to which it is entitled. On its original 1994 and 1995 returns petitioner reported the claimed QREs as costs of goods sold. The supply items that are in dispute are raw materials used to produce goods for sale.

For purposes of resolving this action expeditiously, the parties have agreed to try five of the largest projects underlying petitioner's affirmative research credit claims.[7] The five claim projects are referred to as: (1) The Amoco anticoking

[7]The parties have not specified how they will proceed as to the remaining credit year projects. The Court hopes that this opinion will provide the parties with sufficient guidance to determine whether additional research credits are available for those projects. However, additional proceedings may be necessary if the parties cannot agree on the final disposition of the remaining projects.

project; (2) the spuds project;[8] (3) the sodium borohydride project; (4) the UOP GA-155 project; and (5) the UCAT-J project.

The Court held two special trial sessions in connection with the petition claims. The first addressed the research credit eligibility of the claim projects, and the second addressed petitioner's section 41(c) base amount recomputation. Both parties introduced fact testimony from former UCC employees (in some instances, current Dow employees) and opinion testimony from expert witnesses.

II. Claim Projects

UCC conducted the claim projects at the Taft Plant (Taft) and the Star Plant (Star), both of which were in Hahnville, Louisiana.[9] UCC conducted its olefins production at Taft's hydrocarbons unit, which contained two production subunits designated Olefins-1 and Olefins-2. During the credit years Taft was a manufacturing plant that included facilities for the conversion of raw hydrocarbon feedstocks such as ethane, propane, and naphtha into basic olefins such as ethylene, propylene, and butadiene. The Amoco anticoking, spuds, sodium borohydride, and

[8]Petitioner now concedes that the spuds project is not qualified research. However, for reasons discussed below, we will make an independent determination as to whether the spuds project constitutes qualified research.

[9]Following Dow's acquisition of UCC in 2001, Taft and Star were integrated into a single petrochemical complex referred to as St. Charles Operations.

UOP GA-155 projects related to the olefins production process and were conducted at Taft.

UCC produced film and molding polyethylene resins using petitioner's low pressure UNIPOL process technology at Star. The UCAT-J project related to UCC's production of polyethylene resins and was conducted at Star.

A. The Olefins Production Process

A highly simplified description of the olefins production process at Taft is that hydrocarbon feedstock is pumped from storage into pyrolysis furnaces, preheated, and diluted with steam and then is broken into lighter hydrocarbons through thermal cracking. Hydrocarbons are any chemical compounds consisting primarily of carbon and hydrogen. Hydrocarbons may include 1 to more than 60 carbon atoms and can be gases, liquids, or solids at normal temperatures depending on the number of carbon atoms in the compound. Hydrocarbons are found in petroleum, coal, and natural gas. Hydrocarbons are significant sources of fuel and raw materials for the production of basic petrochemicals and derivatives such as plastics, rubbers, and specialty chemicals.

"Cracking" is the process whereby hydrocarbon molecules are decomposed and recombined into lighter, commercially useful molecules through the breaking of carbon-to-carbon or carbon-to-hydrogen bonds. Cracking can be accomplished through a thermal

or a catalytic process. UCC's olefins production facilities employed a thermal process called "steam cracking", whereby a gaseous or liquid hydrocarbon feed is diluted with steam and heated in a fire furnace. The steam cracking reaction requires temperatures in the range of 1400 to 1650 degrees Fahrenheit and ordinarily occurs for less than half a second before being "quenched", or cooled rapidly, in a heat exchanger or by direct contact with colder fluid. UCC's heat exchangers are typically referred to by the acronym "TLE", which stands for "transfer line exchanger". A TLE tubesheet is a flat, circular sheet approximately 5 feet in diameter that manifolds together many double concentric tubes each with an inner diameter of about 1 inch. Water and steam flow through the concentric annulus of each double concentric tube, and the very high temperature effluent flows through the center tube. Heat is transferred from the cracked gas, or "effluent", to the water and steam to quench the ethylene furnace reaction products. TLEs use the extremely hot effluent to boil water into high pressure steam that may be used to power large steam turbine drivers in the product recovery section of the plant or for other purposes.

The steam cracking process requires the construction and maintenance of large, capital intensive, and complex cracking furnaces to supply the necessary heat. Most of the furnaces at Olefins-1 and 2 were Lummus SRT (SRT stands for "short residence

time”) furnaces. A Lummus SRT furnace consists of a rectangular firebox with a row of vertical tubular coils, or “cracking sets”, located in the center plane between two radiating ceramic refractory walls.

After the effluent is initially quenched in the furnace’s TLE to minimize secondary chemical reactions, it is further quenched through direct contact with water and/or oil in a quench tower. Heavier hydrocarbons, known as “pyrolysis fuel oil”, are separated from the effluent during the quenching process. The cracking, quenching, and pyrolysis fuel oil separation processes occur in the hot section of UCC’s olefins production units.

After quenching, the effluent enters the recovery section (or cold section) of the olefins production units. The effluent is first compressed in a multistage centrifugal compressor to the pressure required for separation. Acid gasses such as carbon dioxide and hydrogen sulfide are removed in an acid gas removal unit during the compression process.

Following compression and acid gas removal, the effluent is dried, chilled, and partially condensed. It then proceeds through a separations train whereby ethylene, propylene, butadiene, and byproducts are fractionated and recovered in a series of distillation columns and related equipment.

Distillation is performed in a column through the application of heat from a reboiler at the column’s base and the

removal of components in a condenser at the column's top. The lighter fraction in the column feed mixture (the fraction containing the components of the mixture with the lower boiling points) is separated according to the lower boiling points relative to the other chemicals in the mixture and recovered as overhead vapor at the top of the column. The heavier fractions in the column feed mixture exit as "bottoms" through the column's base.

Olefins-1 and Olefins-2 each had several distillation columns, including the demethanizer (C_1) column, which separated methane from less volatile components; the deethanizer (C_2) column, which separated ethylene and ethane from less volatile components; the depropanizer (C_3) column, which separated propylene and propane from less volatile components; and the debutanizer (C_4) column, which separated crude butadiene, butane, and other four-carbon compounds from less volatile components. The units also included an ethylene fractionator, which separated ethylene from ethane, and a propylene fractionator, which separated propylene from propane, as well as several other columns.

Recovered methane and hydrogen were used primarily as fuel gas. UCC typically supplied recovered ethylene, propylene, and crude butadiene to third parties and/or one of UCC's dedicated olefins derivatives units. UCC also recovered and sold certain

byproducts of the olefins production process, such as acetylene, dripolene (pygas), and fuel oil. Ethane and propane recovered in the process were recycled through the process to extinction.

B. The Amoco Anticoking Project

1. Overview of Coking

Coke is a heavy, hard, and relatively brittle form of carbon that gradually forms on the interior walls of cracking set coils during the cracking process. The cracking reaction produces two types of coke, “catalytic” and “thermal”.[10] Catalytic coking is caused by the reaction between active metal sites on the inner furnace tube walls and hydrocarbon molecules in the cracked furnace gas. Thermal coking gradually forms as a result of the reaction between catalytic coke and the highly reactive products in the cracked furnace gas. Time and temperature combine to remove the hydrogen from the hydrocarbon molecules, forming thermal coke.

Coke buildup adversely influences furnace performance in a number of ways. Coke insulates the furnace tubes from the inside, impeding effective heat transfer from the furnace walls to the gas within the cracking sets. This gradually increases the skin temperature of the coils to the mechanical limit, approximately 2,000 degrees Fahrenheit. Coil coking also closes

[10]There are other coke formation theories that are not relevant here.

off the flow cross-section area within the cracking sets and thereby causes the hydrocarbon partial pressure (the pressure exerted by the hydrocarbons within the gas mixture) to increase. Higher partial pressure in the coils reduces the desired ethylene yield from the furnace.

Coke also accumulates in the TLEs, located immediately downstream from the radiant section, and the accumulation can lead to higher hydrocarbon partial pressures and TLE exit temperatures. Higher pressure in the TLEs caused by coking also reduces the desired ethylene yield from the furnace.

Because of these effects of coking on furnace operation, the cracking sets must be decoked periodically. UCC generally decoked the furnaces in Taft's hydrocarbons unit every 30 to 60 days through a process in which air and steam were fed into the cracking sets at elevated temperatures (hot decokes). After approximately three to four hot decokes, UCC brought the furnaces down for an extended "cold turnaround" in which damaged cracking sets were replaced and coke was manually removed from the TLE system. Hot decokes and cold turnarounds necessarily resulted in maintenance costs and lost production. Inhibiting coke formation could result in reduced maintenance, longer furnace run times, longer equipment life, and increased productivity.

2. The Coke Reduction Program and Amoco's Technology

Before and during the credit years UCC's hydrocarbons R&D group had in place a coke reduction program aimed at achieving economic and productivity improvements by implementing technologies designed to reduce or eliminate coke in UCC's ethylene furnaces. Because of the inefficiencies caused by coke, finding ways to reduce or eliminate coke was an important objective of UCC's hydrocarbons business. The goal of the coke reduction program was to reduce the number of decokes per year by 50 percent and increase productivity by 4 to 4.5 percent per year. If successful, UCC estimated that this would reduce its decoking costs by $2.4 million per year and increase revenue by as much as $20 million.

Many coke mitigation technologies have been proposed and developed in laboratories over the years, but none have succeeded commercially. Some failed to mitigate coke or even made it worse. UCC screened and commercially tested numerous anticoking technologies in the mid-1980s and later. During the credit years there was no known, generally accepted, commercial coke mitigation technology for pyrolysis furnaces. UCC considered at least four technologies during the credit years but tested only technology developed by Amoco Chemical Corp. (Amoco) during that period.

One of UCC's senior engineering scientists, David Milks, approached Amoco regarding its anticoking technology in January 1994. Dr. Milks operated out of the South Charleston technical center. On January 21, 1994, Amoco's anticoking technology manager wrote to UCC regarding an Amoco-developed furnace anticoking technology that would mitigate coke formation and extend furnace run times between decokings. Amoco's technology involved the pretreatment of the interior walls of the cracking sets with a solution of dithiophosphoric acid derivative. Amoco claimed that the pretreatment bonded to the sites of the tube walls that promote catalytic coke formation and "poisoned" these sites for several furnace runs to prevent coke buildup. Amoco told UCC that its anticoking technology had been successfully tested in a pilot plant and two commercial plants and that the treatment had been shown to survive multiple decokes. After reading about the science behind the technology, Dr. Milks believed that it was theoretically sound but not yet proven. Both Dr. Milks and Amoco were interested in testing the technology on UCC's facilities.

Several UCC employees formed the Amoco anticoking technology test team to evaluate the technology on one of the furnaces at Olefins-2 and to provide a recommendation as to whether UCC should license the technology and implement it on all of its furnaces at Taft and other UCC plants. William Hyde, an

operations improvement engineer at Taft, was the team leader. As the team leader, Mr. Hyde prepared a charter for the team, evaluated the technology to determine whether it was worth testing, and coordinated the testing of the technology.

Amoco's anticoking technology included the treating chemical and a specialized method of application. Unlike prior decoking technologies that UCC had tested, which involved the continuous injection of an anticoking chemical, Amoco's technology was a pretreatment to be applied to a clean furnace before introducing the feed.

Because of the proprietary nature of the technology, Amoco required the protection of a secrecy agreement before disclosing its process to UCC. On or about November 23, 1994, UCC entered into an agreement with Amoco relating to Amoco's anticoking technology (the secrecy agreement). The secrecy agreement was the only agreement UCC entered into with Amoco regarding Amoco's anticoking technology. According to the secrecy agreement, UCC's goal in conducting the Amoco anticoking project was to evaluate the technical and economic feasibility of Amoco's process and equipment for inhibiting coking in UCC's ethylene furnaces. UCC also wanted to determine whether it was interested in a licensing arrangement with Amoco. UCC's rights in Amoco's technology were limited to these purposes. The secrecy agreement obligated UCC to provide Amoco with a nonconfidential summary of the Amoco

anticoking technology's performance no later than 3 months after testing was completed. UCC gained no rights in, or licenses to, any Amoco patent, but the secrecy agreement contemplated that the parties could enter into a licensing agreement after the testing was completed.

3. The Amoco Anticoking Project

At the beginning of the Amoco anticoking project UCC was under the impression that the Amoco technology was fairly established and beyond early developmental stages but that it would still require some testing before it was proven technology. Except for the fact that UCC was testing the Amoco technology, UCC intended to continue its ethylene production process as usual without decreasing production during the Amoco anticoking project.

UCC worked with Amoco to draft a test plan that specified the number of test runs (runs), the run lengths, what would be measured, and the method of injecting the inhibitor. The run lengths would be determined by "furnace cycles", the amount of time the furnace would run between hot decokes under normal operating conditions. The test plan called for the collection of data over four consecutive furnace cycles. The testing would begin on furnace 24 in Taft's Olefins-2 unit. The test plan provided that Amoco would apply the inhibitor to four of the six coils in the furnace so that the coke formation could be compared

between the treated cracking sets and the untreated cracking sets. The test plan provided that treating four of the six coils would ensure that the test results would not be affected by differences between furnaces or operating conditions.

The test plan called for the collection of various measurements during decokes, including furnace coil skin temperature, pressure drop across the coils, TLE inlet pressure, carbon monoxide, carbon dioxide, and phosphine. Except for phosphine, these measurements are affected by coke formation. Phosphine is a toxic substance that can be produced when phosphorous-containing materials are used as coke inhibitors.

To prepare for the test, Mr. Hyde prepared a Facility Operational Change Review (FOCR) for the project. An FOCR is a document that is prepared by the operations personnel when a significant operational change is to take place. It generally addresses technical, quality, health, waste, and safety issues that must be considered before the change is implemented in order to minimize any risks involved. Jason Tregre, a Taft hydrocarbon R&D technology manager, participated in the prestartup safety review on furnace 24. As part of the test preparation UCC also manufactured and installed nozzles according to design specifications provided by Amoco. Among the other final test preparations were several discussions with Amoco representatives

and a walkthrough at Taft on November 7, 1994, in which Amoco and UCC personnel reviewed the pretreatment application procedures.

On or about November 28, 1994, after a hot decoke, four of the six cracking sets were treated. Amoco personnel worked with UCC's plant operators to apply the treatment using Amoco's equipment. Amoco provided the treatment free of charge and agreed to pay any overtime for additional time that UCC's employees would be required to work. The treatment was completed on November 30, 1994. After the pretreatment was complete, UCC's plant personnel returned the furnace to normal operating conditions.

UCC paid for the feedstocks and fuel gases used during the project as well as the normal wages of the UCC employees involved in the project. The supplies used for the project were the same supplies that UCC used for normal operations, and UCC sold the materials produced during the Amoco anticoking project in the ordinary course of its business. The Amoco anticoking project did not disrupt UCC's normal manufacturing processes or products.

After the pretreatment was applied, UCC's plant personnel took various measurements, including the following, some of which were not normally taken and others of which were not normally taken as frequently:

Measurement Taken	Frequency During Test	Normal Frequency
Furnace coil skin temperature	Once per day	Once every 1 to 3 days
Radiant coil pressure drop	At least once per day	Not normally measured
TLE inlet pressure	Continuously	Continuously
Carbon monoxide	Not specified	Not normally measured
Carbon dioxide	During the decoke	Not normally measured
Hydrocarbon and steam flows	Every 6 minutes for the first 7 days, hourly thereafter	Not specified
Phosphine	Not specified	Not normally measured

Some of these measurements were collected on the Olefins-2 unit's process computer, and others were collected manually.

UCC took measurements for approximately 45 days, then performed a hot decoke of furnace 24 in January 1995. Throughout the project UCC continued to decoke furnace 24 according to the plant's normal schedule. UCC restarted the furnace on or about January 15, 1995, without retreating the furnace and continued to take measurements for about 9 days thereafter.

Dr. Hyde compiled these measurements and sent them to Dr. Milks and Dr. Husebye, a researcher in the hydrocarbons R&D group

at the South Charleston technical center. Dr. Husebye reformatted the data and analyzed them. Dr. Husebye did not typically perform this type of analysis. UCC did not share the data it collected with Amoco.[11]

Dr. Husebye and Dr. Milks documented the results of the first Amoco pretreatment in a report dated February 21, 1995. The report covered approximately 7 weeks of furnace 24's operation. The results showed that carbon monoxide in the treated cracking sets was initially reduced, indicating successful coke inhibition. However, after the first hot decoke and restart of furnace 24, there was no statistically significant difference in the amount of carbon monoxide in the treated versus untreated cracking sets. Dr. Milks and Dr. Husebye hypothesized that the hot decoke that was performed before the Amoco pretreatment was applied might have been incomplete and the pretreatment might not have survived the first hot decoke following the pretreatment. The results from the other measurements were either inconclusive or indicated no difference between the treated and untreated cracking sets.

Because the results from the first pretreatment were inconclusive, Dr. Milks and Dr. Husebye recommended a second pretreatment with the Amoco technology after a thorough cold

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[11]Respondent argues that UCC did share data it collected with Amoco, and there is conflicting testimony on this point. However, this fact does not control our decision.

turnaround. Amoco personnel applied the second pretreatment in April 1995 to four of the six cracking sets. UCC personnel gathered the same data following the second pretreatment as they had gathered following the first pretreatment, and Dr. Husebye analyzed the data. While UCC did not retain its analysis of the second pretreatment, it did retain archived computer records that included data collected after the second pretreatment that could be used to reconstruct the original analysis.

Following the second pretreatment, the initial carbon monoxide levels in the treated cracking sets were again significantly lower than the carbon monoxide levels in the untreated sets. However, after the hot decokes of furnace 24 in May and June 1995, the carbon monoxide levels in the treated and untreated cracking sets were nearly identical. The results from the second pretreatment, as a whole, indicated that the Amoco technology did not inhibit coke formation in furnace 24's treated cracking sets during the runs conducted between April and mid-August 1995.

On August 21, 1995, a furnace operator participating in a cold turnaround of furnace 24 observed that the TLE cones connected to the treated cracking sets had significantly greater amounts of coke deposits than the TLE cones connected to the untreated cracking sets. This was unexpected, and UCC believed

that the pretreatment may have contributed to the excess coke in the TLE cones.

During the cold turnaround UCC removed tube samples and coke samples from furnace 24 to be tested. UCC's corrosion and machinery engineering department evaluated the samples and documented the results of its analysis in a formal project report. This report included the results of several tests performed on the samples, analyses of those tests, and recommendations for future tests of the Amoco technology. UCC did not prepare any other formal project reports to specifically document the results of the second pretreatment. However, UCC reported the results of the two pretreatments in several informal reports and memoranda.

UCC considered the Amoco anticoking project to be finished in August 1995, and UCC never again tested the Amoco technology in any of its ethylene furnaces. UCC later discovered that the problem might have been caused by a mistake on Amoco's part in establishing the feed rate or the quantity of inhibitor to be fed to the furnaces. This indicated to UCC that Amoco's technology was more developmental than UCC originally believed it to be. UCC never entered into a licensing agreement with Amoco to use its technology.

UCC used the information gathered during the Amoco anticoking project primarily to determine that Amoco's technology

did not effectively reduce coke formation in its commercial facilities. UCC also learned about the operation of thiophosphates (the active ingredients in the Amoco technology), the relationship between sulfur and carbon monoxide levels, and the effect of anticoking technology on the ceramic material on TLE cones. UCC used this information in the course of its business.

Mr. Hyde spent 35 hours in 1994 and 10 hours in 1995 working on the Amoco anticoking project. Mr. Tregre spent 5 hours working on the Amoco anticoking project in 1994.[12]

C. The Spuds Project

1. Overview of the Spuds Project

The spuds project involved replacing four-hole spuds with one-hole spuds on furnace 3 in Olefins-1 at Taft. The one-hole spuds were installed on furnace 3 on or about January 13, 1995.

A burner is a device that provides radiant heat in a pyrolysis furnace through controlled combustion. In a pyrolysis furnace, combustion is intended to provide a uniform temperature to the fired radiant wall, allowing for even heat flux distribution to the cracking set coils.

[12]Petitioner does not claim as QREs any wages paid to Dr. Milks or Dr. Husebye, who operated out of the South Charleston technical center. Their wages would have been included in petitioner's original returns research credits.

The furnaces in Olefins-1 each had 112 radiant wall burners. The burners are mounted through the furnace radiant wall and produced a thin, flat circular disk of flame adjacent to the wall. The burners were equally spaced in a grid pattern and radiated heat to the process tubes on the centerline of the furnace. Each burner had a single spud.

A spud is the orifice or port through which fuel gas flows into the burner. It resembles a bolt with one or more holes at the end. Spuds are installed at the piping terminations of each burner and affect fuel flow and pressure. Spuds function to equally divide the amount of fuel being injected to each burner so that the heat released from the burners is evenly and predictably distributed throughout all of the burners in the firebox. The size and number of spud orifices determine the pressure of the fuel gas just upstream of the orifice and the exit velocity of the fuel gas from the orifice, parameters known as “flow characteristics”. Flow characteristics of the spuds help determine the burner firing capacity, which is the British Thermal Unit (BTU) per hour heat output generated by a single burner, flame stability, and fuel efficiency. As fuel gas passes through the spud it produces a high velocity gas jet, which entrains combustion air and mixes it with the fuel. The amount of air that mixes with the fuel is critical to the stability of the flame.

When it was first built in the 1960s, Olefins-1 used one-hole spuds until it was moth-balled in the 1980s. When it was restarted in 1989, Olefins-1 switched to four-hole spuds in order to reduce noise. The four-hole spuds were prone to plugging, and UCC typically cleaned the spuds during furnace shutdowns by poking them with pieces of wire. Plugging of spuds may also be improved or eliminated by cleaning the fuel gas system, removing contaminants in the fuel gas, setting up a regular maintenance schedule for removing and cleaning the spuds, or increasing the size of the orifice(s) in the spuds. Some of these methods may be costly and/or labor intensive. While replacing multihole spuds with one-hole spuds without changing the total area of the holes was a known method of reducing plugging, one-hole spuds cause significantly more noise than multihole spuds and therefore cannot always be used.

The Taft hydrocarbons unit identified fuel efficiency as an area for operational improvement. In October 1994 the John Zink Co. conducted a combustion survey of Taft’s hydrocarbons unit. The John Zink Co. is a large ethylene burner manufacturer that manufactured the burner used on furnace 3. Burner manufacturers generally use their test furnaces to evaluate new spud designs because testing new spuds in a commercial furnace can be hazardous and the costs are unreasonably high. However, once a spud design is proven, it generally performs better on commercial

furnaces than on test furnaces because the higher heat content in a commercial furnace results in more stable flames. Testing and evaluating a new spud on a test furnace takes about a day or less.

Following the survey, the John Zink Co. recommended using one-hole spuds instead of four-hole spuds in the Olefins-1 furnaces to reduce plugging. UCC had been using one-hole spuds in its Olefins-2 furnaces since the late 1970s and noticed that Olefins-2 had not experienced any plugging problems. However, UCC was concerned about changing to one-hole spuds because they might create too much noise. Olefins-1 and 2 were physically different, and noise was more of a concern at Olefins-1 than at Olefins-2. However, noise was not a major concern because the plant personnel already wore hearing protection.

UCC followed the John Zink Co.'s recommendation to try switching from four-hole spuds to spuds with one hole with the same total hole area. UCC decided to purchase enough spuds for three furnaces, which would cost $3,400 to $3,700 per furnace. UCC believed that this was a relatively inexpensive way to solve the plugging problem. UCC intended to test the new spuds on one furnace; and if the test was successful, then UCC would immediately begin replacing the spuds on two other furnaces.

To test the new spuds, UCC planned to monitor performance data such as: (1) The fuel-to-feed ratio (BTUs of fuel per point

of feed), (2) excess oxygen in the fuel gas, (3) the amount of combustibles in the fuel gas, and (4) fuel pressure. UCC intended to evaluate the fuel efficiency improvements by measuring BTUs in a process computer, measurements that were available regardless of whether a test was being performed. The goals of the test were to determine whether the new spuds would: (1) Stop or reduce plugging; (2) increase efficiency, and if so by how much; and (3) increase noise, and if so by how much. Mr. Tregre was involved in this planning.

UCC did in fact take the above test data on furnace 3 for about 90 days. Mr. James Gorenflo, a furnace technician, was involved in testing furnace 3. UCC monitored plugging by checking fuel pressure gauges. The results showed that pressure was not increasing, which indicated that the new spuds solved the plugging problem. UCC also evaluated fuel efficiency by analyzing measurements of fuel gravity and the fuel-to-feed ratio. Mr. Tregre was involved in this evaluation. The results showed that fuel efficiency improved, although not as dramatically as UCC had hoped.

Because the one-hole spuds solved the plugging problem, UCC installed one-hole spuds on all of its furnaces at Olefins-1 after the 90-day test period was over. While UCC hoped that the change would increase fuel efficiency more, the fact that the

one-hole spuds solved the plugging problem was sufficient justification for changing the spuds.

Mr. Tregre spent 70 hours in 1994 and 10 hours in 1995 working on the spuds project. Mr. Gorenflo spent 10 hours in 1995 working on the spuds project.

2. Petitioner's Motion for Leave To Amend Its Petition

On January 19, 2007, petitioner filed a motion for leave to amend its petition. If filed, the amended petition would have: (1) Withdrawn petitioner's affirmative claim for additional research credits under section 41 to the extent it was based on the spuds project, (2) adjusted the claimed QREs to reflect the withdrawal of the spuds project, and (3) applied the correct credit rate for 1994. Respondent opposed this motion because the Court had already held a trial on the claim projects, including the spuds project. Given the substantial cost of litigation, respondent argued that he would be prejudiced if the Court was prevented from rendering a decision on whether the spuds project satisfied the criteria for qualified research. In addition, to the extent that petitioner claimed additional research credits for projects similar to the spuds project that were not litigated in the claim year trial, respondent argued that he would be prejudiced by the absence of a decision on whether the spuds project constituted qualified research.

Following a hearing on this motion on August 29, 2007, we denied petitioner's motion because we found that it would be unfair to allow petitioner to unilaterally alter its agreement with respondent to hold a trial on the five claim projects.

D. The Sodium Borohydride Project

1. Overview of the Acid Gas Removal System

The sodium borohydride project involved the injection of a sodium borohydride solution into the Olefins-2 caustic scrubber.

The Olefins-1 and Olefins-2 acid gas removal systems remove carbon dioxide and hydrogen sulfide from cracked furnace gas. Acid gases are impurities that can cause operational problems in downstream plant equipment. Acid gas removal is also necessary to meet product specifications.

The acid gas removal system consists of a regenerative monoethanolamine (MEA) system followed by a caustic scrubber. Cracked furnace gas is fed into the MEA system, where it is washed with a countercurrent flow of amine solution that removes the bulk of acid gases. As an incidental benefit the MEA system removes the impurity acetaldehyde from the cracked furnace gas. Acetaldehyde is a highly reactive compound created in trace quantities during the thermal cracking of hydrocarbons in the presence of steam. It is formed in the furnaces through the interaction of free radicals from steam and ethane or other raw materials. Acetaldehyde can polymerize and foul plant equipment.

After being treated by the MEA system, the cracked furnace gas passes through a two-stage caustic scrubber for removal of residual acid gases. The caustic scrubber is sized so that it can reduce acid gases to specification levels even when the MEA system is shut down.

The MEA systems in both Olefins-1 and Olefins-2 had to be periodically shut down and manually cleaned because of the fouling of heat transfer surfaces partially caused by acetaldehyde polymerization. Fouling is the deposition of heavy organic solids that were dissolved in process fluid. When one of the MEA systems is down, the cracked furnace gas passes through only the caustic scrubber for acid gas removal. The caustic scrubber, however, does not remove acetaldehyde. Taft's MEA systems ordinarily ran from 3 to 6 months between shutdowns, depending on the feedstocks used and furnace cracking conditions. Cleaning the MEA system normally took about 14 days.

In the early 1990s UCC produced at its Taft plant a hydrocarbon product called crude butadiene. Crude butadiene is highly reactive and is a major contributor to fouling in the olefins process equipment. When the MEA system was shut down and only the caustic scrubber was used to remove acid gases, some acetaldehyde would leave the process with the crude butadiene.

In 1994 Shell Oil Co. (Shell) was Taft's primary customer for crude butadiene. At the time, Taft stored crude butadiene in

two storage tanks and transported it in barges to Shell, which operated a plant directly across the Mississippi River from Taft. Shell had a product specification limiting the amount of acetaldehyde in Taft's crude butadiene to 100 parts per million (ppm) because acetaldehyde would foul Shell's processing equipment. On one occasion in the summer of 1994, UCC manufactured crude butadiene that did not meet Shell's acetaldehyde specification. Shell refused to accept a barge shipment of that crude butadiene and returned it to Taft.

When the MEA system was in service, acetaldehyde levels in Taft's crude butadiene were well below 100 ppm. However, acetaldehyde levels reached between 500 and 800 ppm when the MEA system was shut down. One method that UCC used to bring off-specification crude butadiene within specification levels was called "blending". UCC would store off-specification crude butadiene and then blend it with on-specification crude butadiene when the MEA system was restarted.

However, when the amount of off-specification crude butadiene exceeded UCC's available storage capacity, UCC would have to attempt to recycle the crude butadiene or find a purchaser who would accept it as it was. Another problem of blending was that it was difficult to calculate the amount of on-specification product needed to blend with the off-specification product. UCC was also considering building a pipeline directly

from Taft to the Shell plant, which would reduce or eliminate the need for storage tanks and make blending impractical. Therefore, UCC did not view blending as a permanent solution to the problem of off-specification crude butadiene.

2. The Sodium Borohydride Project

Because of the shortcomings of blending, UCC sought a way to remove acetaldehyde from crude butadiene during the periods that the MEA system was shut down for maintenance. UCC decided that a possible solution was to add sodium borohydride to the caustic scrubber to remove acetaldehyde when the MEA system was shut down for maintenance.

In February 1995 UCC considered using sodium borohydride regularly to remove acetaldehyde if using sodium borohydride proved to be effective. UCC knew that sodium borohydride was effective in removing aldehydes, including acetaldehyde, as UCC had been testing sodium borohydride in laboratories for such purposes as early as 1961. UCC and its competitors had successfully used sodium borohydride in commercial processes to remove acetaldehyde and other carbonyl compounds from products. However, UCC did not know how effectively sodium borohydride could remove acetaldehyde in the caustic scrubber. Liquid sodium borohydride was often used to remove acetaldehyde from other liquids, but in the caustic scrubber UCC would need to use liquid sodium borohydride to remove acetaldehyde from a gas. The

interaction of a liquid with a gas is much more difficult to predict than the interaction of a liquid with other liquids.

UCC also knew that sodium bisulfate could be used to remove acetaldehyde. However, UCC would have had to use a higher concentration of sodium bisulfate than sodium borohydride to effectively remove acetaldehyde, and sodium bisulfate was more difficult to work with than sodium borohydride.

On October 10, 1994, Mr. George Brandon, a senior production specialist at Taft, initiated an FOCR for injecting sodium borohydride into the caustic scrubber in Olefins-2. According to the FOCR, the purpose of the project was to run a test to determine whether sodium borohydride could be used to remove acetaldehyde when the MEA system was shut down.

An R&D report dated January 9, 1995, prepared by Robert Manyik, a consultant in the hydrocarbons R&D group, was attached to the FOCR. In the R&D report Dr. Manyik proposed a plant test to add sodium borohydride to the caustic scrubber when the MEA system was down in order to remove acetaldehyde to on-specification levels. UCC would use a sodium borohydride solution called VenPure, sold by Morton Performance Chemicals (Morton). The R&D report addressed whether such a test was feasible, identified potential hazards that could arise during a test, and provided the necessary technical information that would be needed to conduct the test. The R&D report specified the

equipment that was available, how much sodium borohydride UCC would purchase, the rate at which the sodium borohydride would be added, and the benefits and drawbacks of diluting the sodium borohydride. The FOCR also included a diagram illustrating how the sodium borohydride would be injected and a memorandum setting out, in question and answer format, the duration of the test, the controls that would be monitored, whether the sodium borohydride would be diluted, the physical configuration of the injection equipment, operation temperatures and pressures for the injection equipment, and UCC's plan to prevent the buildup of salt precipitates.

One of the departments that reviewed the FOCR was Taft's Environmental Pollution Department (EPD). The EPD endorsed the sodium borohydride project provided that certain conditions were met. These conditions were that the EPD would sample and monitor the plant's wastewater for the presence of boron 2 weeks before, during, and 2 weeks after the test, and the use of sodium borohydride would be immediately terminated if the monitoring indicated that the wastewater quality was beginning to deteriorate. The EPD was concerned that large amounts of boron might enter the wastewater system and disrupt the wastewater treatment. Another condition that the EDP imposed was that the injection rate would not exceed 5 pounds per hour; and if the

plant was required to increase this rate, it would seek approval from the EPD at that time.

Approval from UCC's R&D department was also necessary before beginning the project because it involved the introduction of a new chemical to the process. UCC wanted to ensure that the change was safe and that there would be no adverse consequences to the plant process from the injection of sodium borohydride. The R&D department approved the sodium borohydride project on January 13, 1995, and the engineering department approved the sodium borohydride project on February 20, 1995.

UCC believed that a plant test was necessary to determine whether sodium borohydride would effectively remove acetaldehyde in an actual caustic scrubber. UCC was uncertain how well the sodium borohydride would mix with the acetaldehyde because of the difficulty in modeling liquid-gas interactions. Therefore, while it was known that sodium borohydride would react with acetaldehyde in a laboratory or pilot plant setting, UCC was not sure how well sodium borohydride and acetaldehyde would react in a full-scale plant given the plant's size, gas flow, and configuration. Because cracked furnace gas travels quickly through the caustic scrubber, UCC was unsure whether the residence time of the sodium borohydride in the caustic scrubber would give the sodium borohydride sufficient time to react with the acetaldehyde and bring the crude butadiene within

specification levels. UCC was also unsure of the appropriate rate to inject the sodium borohydride and of the effect the sodium borohydride would have on the boron concentration of the wastewater. Because of these uncertainties as to how sodium borohydride would interact with acetaldehyde, UCC referred to the sodium borohydride project as a “test run”.

After injecting the sodium borohydride, UCC intended to monitor the acetaldehyde content of crude butadiene extracted from the caustic scrubber. The EPD also planned to monitor the wastewater for boron content.

The equipment for the sodium borohydride project was initially installed at Olefins-1 on June 11, 1995, but the crude butadiene remained within specification levels when the Olefins-1 unit’s MEA system was shut down for maintenance. Accordingly, UCC moved the equipment to Olefins-2 and conducted the test there. UCC had a limited amount of sodium borohydride and did not want to waste it on crude butadiene that was already on-specification. The sodium borohydride project began in the Olefins-2 unit on or about June 12, 1995, and ran for approximately 2 weeks.

During the test, UCC injected the sodium borohydride solution into the Olefins-2 caustic scrubber. To inject the sodium borohydride UCC used a small tote tank (owned by Morton) to hold the solution, a small metering pump to inject the

solution, and tubing to connect the tank and the pump to the process. Morton recommended an amount for UCC to inject, and UCC followed that recommendation initially but then made adjustments as the project progressed. UCC did not regularly record the amount of sodium borohydride that was injected during the test.

Taft employees monitored the crude butadiene production from the Olefins-2 unit's C_4 column during the sodium borohydride project. UCC measured the acetaldehyde content of the crude butadiene every 12 hours. UCC normally took these measurements about three times a week. To take the measurements, plant operators took samples of crude butadiene to Taft's central quality control laboratory for testing. In addition, Mr. Brandon measured acetaldehyde levels in the cracked furnace gas entering and exiting the caustic scrubber. To take these measurements, Mr. Brandon used a device called a "drager pump and tube system". The tubes would indicate how many ppm of acetaldehyde the cracked gas contained. Mr. Brandon took these measurements at least daily for the duration of the project. Mr. Brandon did not normally take such measurements. As planned, the EPD also monitored the wastewater approximately every 12 hours. The EPD normally monitored the wastewater weekly unless a special test was being run.

Mr. Brandon collected and recorded the results of the crude butadiene analyses and drager tube tests and reported the results

to Terry Swindle, a Taft engineer assisting with the sodium borohydride project. Mr. Brandon devoted approximately 200 hours to the sodium borohydride project. The EPD collected and recorded the results of the wastewater monitoring and reported to Mr. Swindle that the boron was within acceptable limits. However, the data collected from the sodium borohydride project were not documented in a final project report. UCC treated the January 9, 1995, R&D report prepared by Dr. Manyik as the functional equivalent of a project report even though the report was prepared before the test of sodium borohydride occurred.

UCC considered the sodium borohydride project to be a success because the sodium borohydride effectively kept the acetaldehyde in the crude butadiene production below the 100 ppm specification level. Accordingly, Taft began to use sodium borohydride regularly to reduce acetaldehyde levels when an MEA system was shut down.

Several years later, UCC discovered that using sodium borohydride to remove acetaldehyde caused unacceptably high levels of ethanol, a byproduct of the reaction, in the crude butadiene. During the credit years UCC believed that ethanol would leave the system with the spent caustic and therefore did not consider whether ethanol would be a problem and did not measure it. However, the ethanol remained in the crude butadiene and later caused it to fail Shell’s new specifications.

Therefore, UCC began using a new product to remove acetaldehyde instead of sodium borohydride.

E. UOP GA-155 Project

1. Overview of Fouling in the C_3 Column

The UOP GA-155 project involved the injection of an inhibitor, UOP GA-155, into the C_3 column line at Olefins-1 in an attempt to reduce fouling in the C_3 column trays and reboilers. Fouling is a major problem for petrochemical plants. Consequences of fouling may include declining performance, frequent shutdowns of process equipment, loss of operation time, and increased maintenance costs for cleaning or replacement of equipment.

Fouling is a particular problem in distillation column services. Deposit buildup in distillation columns can reduce capacity and efficiency by blocking the flow path and by impeding the performance of heat exchangers. An ethylene unit can experience polymer fouling in the C_2, C_3, and C_4 distillation columns. The C_3 column typically has the worst fouling problem.

The main function of the C_3 column was to separate the propylene and propane (C_3 molecules) and heavier hydrocarbons. The liquid hydrocarbon steam entered the C_3 column at the column’s midpoint and fell to the bottom where it was heated by one of the two reboilers mounted on the column’s base. The lighter C_3 molecules were vaporized and captured at the top of

the column, while the remaining heavier components exited the bottom of the column and traveled on to the C_4 column. The C_3 column contained approximately 40 trays that held the liquid hydrocarbon stream being processed so that it could be exposed to the vapor generated by the reboiler.

Column fouling is typically greatest within the reboiler and also occurs in the trays. One cause of fouling in distillation columns is the polymerization of reactive components in the liquid phase of distillation. Polymerization is the linking of double bonds to form long chain molecules. Most of the polymerization is due to the reaction of diolefins and reactive species such as styrenics.

In the mid-1990s Olefins-1 was experiencing high levels of fouling in the C_3 columns, reboilers, and internal trays caused by the formation of polybutadiene polymer, a rubbery black substance that adhered to the insides of the column. There were two reboilers mounted to the base of the C_3 column, but only one operated at a time. The polybutadiene polymer fouled the tubes in the operating reboiler and restricted the liquid flow. When the reboiler fouled to the point that it became inoperable, it was taken out of service and cleaned, and the clean reboiler was placed in service. Typically, it took about 2 weeks to clean a fouled reboiler and cost about $25,000. In 1994 and 1995 the

ideal run time for a reboiler between cleanings was 2 to 3 months.

The polybutadiene polymer also accumulated on the trays to the point that the vapors rising from the bottom of the column could not pass through the holes in the tray. This fouling created a high differential pressure in the column, causing the column to flood with liquid and become inoperable. At this point, plant employees would have to shut down the column and clean it. In 1994 and 1995 the ideal run time for a C_3 column was approximately 3 years but, depending on the feedstock, cracking, and operating conditions, the column would not always run that long. It would typically take about a month to clean a fouled C_3 column and cost about $50,000. Occasionally the entire olefins unit needed to be shut down when a column cleaning occurred.

2. Overview of Inhibitors

An inhibitor is a chemical that is added to a chemical plant to reduce fouling and increase the time that a particular piece of equipment will operate before it needs to be cleaned or shut down. Olefins plants use two types of inhibitors (1) polymerization/oxidation inhibitors and (2) dispersants. Polymerization/oxidation inhibitors are added to stabilize certain products that can polymerize or break down when exposed to air. Dispersants are added to products to keep impurities

suspended in the liquid hydrocarbon stream from depositing on plant surfaces and fouling them. An effective inhibitor will improve column and reboiler run length times and will not cause any additional problems in the plant.

UCC used about 12 different inhibitors in its olefins manufacturing processes at any particular time in the early 1990s. In 1994 and 1995 UCC used different inhibitors in its olefins manufacturing units because an inhibitor that works well in one olefins plant may not necessarily work well in another olefins plant. Because equipment differs from plant to plant, an inhibitor might have a different residence time or different contact times in different columns. In addition, flow rates, pressures, and temperatures, which all affect the operation of an inhibitor, differ from plant to plant.

The vendors from whom UCC purchased inhibitors tested the inhibitors in laboratories to verify that they would in fact inhibit polymerization or oxidation. However, UCC could not determine how well the inhibitors would work in one of its plants without testing them in the plant. UCC generally gathered data when using a new inhibitor and compared that data to baseline data to determine whether the inhibitor worked as expected. The purpose of inhibitors is to extend the time equipment can be used before it must be shut down and cleaned. Therefore, one way to know whether an inhibitor is effective is to compare the run time

of a compressor, reboiler, or column operating with the inhibitor against the preinhibitor run time of the same equipment. UCC believed that the test of a new inhibitor should last for about as long as the vendor claims the equipment will run with the use of the inhibitor. UCC also generally used inhibitor tests to determine the proper dosage. While UCC believed it was important to use enough of an inhibitor for it to be effective, excessive use of an inhibitor can have adverse effects on the production process or on the plant's products. Furthermore, because inhibitors are expensive, using a higher dosage than is necessary will reduce the economic benefit of using the inhibitor.

The hydrocarbons R&D group was generally involved in decisions to test process inhibitors at UCC's plants because the tests would involve the introduction of a new chemical into the plant and could have environmental, health, and safety consequences. R&D was familiar with the chemistries and processes of the plants and could provide input on whether a new inhibitor might be effective in the plant, what dosage levels to use, how to set up the test plan, and how to measure the results of the inhibitor use.

3. The UOP GA-155 Project

Dripolene was a byproduct of Taft's olefins production process that flowed out the bottom of the C_4 column, the final column in the olefins separations train. UCC could not ship

dripolene unless it was stabilized with a certain amount of polymerization/oxidation inhibitor. Without the inhibitor, the dripolene could react with oxygen and present an explosion hazard.

Before undertaking the UOP GA-155 project, Taft's hydrocarbons unit had been injecting a stabilizer known as UOP-5 into the dripolene as it flowed out of the C_4 column. The active ingredient of UOP-5 was phenylenediamine. The dripolene from Olefins-1 and 2 was blended and stored in the same tank, so the Olefins-1 dripolene was stabilized by the inhibitor injected into the Olefins-2 dripolene.

Because cleaning the reboilers and shutting down the columns was very expensive, UCC was always looking for ways to decrease operating costs by reducing fouling. Mr. Brandon discussed the problem with members of Taft's hydrocarbons R&D group to try to find ways to reduce fouling in the C_3 column. Mr. Brandon approached UOP, a supplier to the petrochemical industry, to determine whether UOP had a product that could be fed directly into the Olefins-1 C_3 column to both reduce fouling and stabilize the dripolene. UOP reviewed UCC's process stream, operation, equipment, and operating conditions. On the basis of those observations, UOP recommended that UCC use UOP GA-155, which contains phenylenediamine (the active ingredient used in UOP-5) as well as a dispersant. UOP told UCC the approximate

percentages of UOP-5 and the dispersant contained in UOP GA-155. UOP maintained that UOP GA-155 would operate as an oxidation inhibitor in the C_3 column, the phenylenediamine would stabilize the dripolene, and the dispersant would mitigate fouling in the C_3 column. UOP represented to UCC that UOP GA-155 was effective in extending process run length.

UCC had not previously used UOP GA-155 in any of its facilities and was not aware of any other olefins plants in the country that had used UOP GA-155. However, UOP told UCC that some of the ingredients in UOP GA-155 were industry-wide standard materials that were being used in olefins plants. UCC did not consider other possible inhibitors or chemicals because their cost was excessive because they were bundled with the purchase of services that UCC did not want.

UCC wanted to test UOP GA-155 in its plant because successful laboratory tests do not guarantee that an inhibitor will be effective enough in a full-scale plant to justify its cost. While manufacturers often made representations to UCC regarding the inhibitors that they were selling, the inhibitors did not always work as represented.

To test the UOP GA-155, UCC planned to inject UOP GA-155 into the C_3 column feed instead of into the dripolene product as it had done with UOP-5. The UOP GA-155 would then flow out of

the bottom of the C_3 column, flow into the C_4 column feed, and flow out of the C_4 column and the plant with the dripolene.

Mr. Brandon initiated an FOCR, numbered 94-80 (FOCR 94-80), for moving the equipment that was being used to inject UOP-5 into the Olefins-2 dripolene product over to Olefins-1 in order to inject the inhibitor into the C_3 column feed. UCC hoped that injecting the inhibitor into the C_3 column feed instead of injecting it into the dripolene as it flowed out of the C_4 column would inhibit fouling in the depropanizer system. Mr. Brandon initiated another FOCR, numbered 94-61 (FOCR 94-61), for changing the inhibitor from UOP-5 to UOP GA-155 and injecting UOP GA-155 into the C_3 column feed. FOCRs were generally required when introducing new inhibitors because the introduction of a new inhibitor is a process change. According to FOCR 94-61, the purpose of the change was to reduce fouling in the C_3 and C_4 columns and their reboilers. The FOCR listed as concerns that needed resolution (1) whether the customers would approve of the change and (2) whether UCC had a pump that had a high enough discharge pressure.

Mr. Brandon's supervisor instructed Mr. Brandon to keep the UOP GA-155 project on hold until the necessary approvals had been obtained from the hydrocarbons R&D group, the EPD, and UCC's customers. UCC informed its customers that UOP GA-155 would be injected into Taft's Olefins-1 production process, and its

customers did not object. The FOCRs were finally approved on September 22, 1994.

While Mr. Brandon hoped that UOP GA-155 would increase the C_3 column's run time, he was not certain how effective UOP GA-155 would be. Mr. Brandon was also concerned that UOP GA-155 could actually harm UCC's production process. Specifically, he was concerned that adding a dispersant to the column could cause existing polymers to loosen from the column walls and trays and plug the column. If that happened, UCC would have to shut down the column and possibly the entire Olefins-1 unit. In addition, Mr. Brandon was concerned about the effect that UOP GA-155 might have on Taft's commercial products because the UOP GA-155 would flow out with the crude dripolene. Because UOP GA-155 would be a new ingredient in the product, it was possible that it could adversely affect the downstream olefins products or cause problems when fed into customers' production processes.

The injection of UOP GA-155 into the C_3 column feed line in Olefins-1 began soon after the final approvals were obtained for FOCR 94-61 and FOCR 94-80 on September 22, 1994. The hydrocarbons R&D group asked the plant personnel to collect data during the test. Accordingly, Mr. Brandon collected daily all of the pertinent data that were regularly recorded on the process computer system in the Olefins-1 control room, including differential column pressure, feed flows, throughput rate, steam

temperatures, and steam flows. Differential column pressure is the measurement of the different pressures across the column trays from top to bottom. When polybutadiene polymer accumulates on the trays, the trays plug and the differential pressure increases. While UCC did not normally review these measurements daily, UCC did monitor reboiler chest pressure when there were problems. It was also typical in the industry to measure column differential pressure when equipment is prone to fouling.

During the test Mr. Brandon also measured and recorded condensate pressure of the reboiler every day. Neither Mr. Brandon nor any of UCC's other employees had monitored the condensate pressure daily before the UOP GA-155 project. An increase in condensate pressure is a primary indicator of reboiler fouling.

Mr. Brandon and other employees also took samples of dripolene and analyzed the inhibitor levels once per 12-hour shift. Before the UOP GA-155 project, UCC's employees had analyzed the inhibitor levels in the dripolene once a week for quality control. Mr. Brandon took measurements for approximately 90 days during the UOP GA-155 project. Mr. Brandon also kept track of reboiler run lengths both before and during the test period. Mr. Brandon spent approximately 200 hours in 1994 and 200 hours in 1995 working on the UOP GA-155 project.

It would take approximately 3 years to determine whether UOP GA-155 substantially extended the run length of the C_3 column. UCC could determine whether UOP GA-155 was reducing fouling in the column by opening the column, but that was not practical. Therefore, UCC relied on indicators such as differential column pressure to determine whether UOP GA-155 was reducing fouling in the column.

It would take at least 3 months for UCC to assess whether UOP GA-155 would increase the run length of the reboiler because the normal run length of a reboiler without the addition of an inhibitor is about 2 to 3 months. UCC believed that a successful inhibitor could extend the run length of a reboiler to about 6 months. Therefore, while Mr. Brandon recorded data only for about 90 days, UCC treated the project as beginning on September 22, 1994, and lasting for 6 months. During this time the Olefins-1 unit operated normally except for the addition of the activities described above. UCC sold the products produced during the UOP GA-155 project in the ordinary course of its business.

UCC considered the UOP GA-155 project to be a success because it reduced fouling and increased the run length of the reboiler to 6 months.

Mr. Brandon recorded the results of the project and shared them with Mr. Swindle. However, Mr. Brandon did not prepare a

formal project report after the project was completed or save the data for use when fouling of Olefins-2 was discovered in 1997 or 1998. However, the results of the project would have been reported in the quarterly reports that the hydrocarbons R&D group prepared. The results of the UOP GA-155 project were also included in a memorandum prepared for a conference call to be held on July 27, 1995. The memorandum did not include data from the project but reported the results as follows:

> UOP Inhibitor Project: Recall that in the beginning of the second half last year, the UOP-5 inhibitor was replaced with the UOP GA-155 inhibitor and it was injected earlier in the system in order to reduce fouling of the C3 Column Reboilers in Ole-1. In January of this year, the east kettle [reboiler] had to be taken out of service due to tube leaks which were not caused by the inhibitor or fouling - it was due to attack from carbonic acid in the steam condensate. The newly purchased kettle, which was installed last October, was then put in service and is still in service. We feel that the success of the kettle - six month life - is primarily due to the use of the new inhibitor. In addition, the new inhibitor is now also being used in Ole-2.

UCC did not always prepare formal project reports when an inhibitor test such as the UOP GA-155 project was performed. Although it was preferable for a project report to be prepared to summarize the results of an inhibitor test, this did not always happen because it was not always a top priority.

On or about October 28, 1994, about a month after the UOP GA-155 project began, Mr. Brandon began preparing an FOCR for a project to begin using UOP GA-155 in Olefins-2. On November 29,

1994, Mr. Swindle recommended that UOP GA-155 be used at Olefins-2. On or about June 14, 1995, after the completion of the UOP GA-155 project, UCC began injecting UOP GA-155 into Olefins-2's C_2 column tail. The purpose of this change was to reduce fouling in the C_2, C_3, and C_4 columns in Olefins-2 and simultaneously stabilize the dripolene. However, during a plant shutdown in 1997 or 1998, UCC discovered that the dispersant in UOP GA-155 caused severe fouling in the Olefins-2.

F. The UCAT-J Project

1. Overview of Polyethylene Production

The UCAT-J project involved a series of runs using a new polyethylene (PE) catalyst referred to as UCAT-J conducted at Star. PE is a plastic made by reacting ethylene with other materials to form polymers, or molecular chains, of ethylene. The PE production process generally involves a reaction between a polymerization-initiating catalyst (as relevant here, M-1 or UCAT-J[13]), a cocatalyst, a monomer (usually ethylene), a comonomer (hexene or butene), triethylaluminum (TEAl), and hydrogen. Once polymerization begins, monomer molecules diffuse to the growing polymer chains and resin is formed. Following polymerization, the resin is discharged into a separate vessel known as a product purge bin. Purging removes the residual

[13]The UCAT-J and M-1 catalysts are described in greater detail below.

hydrocarbons in the resin and deactivates the catalyst and cocatalyst. The resin is then fed into a pelletizer, which converts the resin into pellets. The pelleted PE resin is the finished product. UCC typically shipped pelleted PE in hopper cars (which each hold about 185,000 pounds of PE resin) to customers who used it to make items such as grocery and trash bags, packaging, thin-walled containers, and industrial liners.

Star was dedicated to the commercial production of linear low-density film and molding resins (LLDPE) and medium density (MDPE) and high density (HDPE) molding resins using UCC's low-pressure UNIPOL process technology. "UNIPOL" is the trade name for a low-pressure gas phase fluidized bed process that UCC developed and licensed to third parties. Star's Low Pressure 3 Unit (LP-3) operated two UNIPOL reactors: Reactor 1, which was used primarily for HDPE molding resins, and Reactor 2, which was used primarily for LLDPE film resins. Although used for different purposes, the two reactors were physically and technologically identical. Reactor 1 and Reactor 2 operated continuously 24 hours a day except for limited downtime maintenance, transitions, and unforeseen problems such as electrical outages.

In the early 1990s UCC began to plan the design of another UNIPOL manufacturing facility, Low Pressure 6 Unit (LP-6). LP-6 was designed to produce PE using UCAT-J as the catalyst, but UCC

decided to install two different sets of catalyst feeders so that M-1 could be used at the plant if UCC could not commercialize UCAT-J by the time LP-6 was complete. UCC believed that it was likely that it would be able to use UCAT-J at LP-6 once it was constructed, but also knew that beginning the design of LP-6 before UCAT-J was ready for commercial production was a risk. UCC did not want to wait until UCAT-J was commercialized before building LP-6 because it takes years to design and build a manufacturing facility and UCC wanted LP-6 to be completed close to the time that UCAT-J was commercialized. LP-6 began producing PE in June of 1995 using UCAT-J.

A UNIPOL reactor is referred to as a “fluidized bed” because the circulating gas flow in the reactor causes the solid granular resin to fluidize. The catalyst is fed directly into the side of the fluidized bed through an injection system. A cocatalyst is also fed into the bottom of the UNIPOL reactor to activate the catalyst and promote catalyst activity.

“Reactor operability” refers to a wide range of potential reactor operating issues, including catalyst stability, reproducibility (whether the reactor consistently produces the same responses), reactor control, production rate control, product discharge, and downstream equipment operation. Reactor operability is affected by a number of factors such as the history of the reactor since it was last cleaned (i.e., how often

it has been exposed to oxygen and moisture), the mix of products run on the reactor, the purity of the feed streams, and the catalysts and cocatalysts used on the reaction system.

A significant UNIPOL operability issue is the formation of sheets and agglomerates caused by static in the reactor. Sheets and agglomerates are often referred to as continuity problems because they interrupt the continuous operation of the reactors. Sheets are formed when resin continues to react in a stagnant zone (a zone with poor fluidization) next to the walls of the reactor. Without fluidization to remove the heat of reaction, the resin fuses together and forms sheet-like blocks ranging from paper thin to several inches in thickness and several feet in length. Agglomerates are formed when granular resin fuses together forming solid or tightly adhered chunks ranging from popcorn sized to several feet in diameter. These chunks can be caused by sheets folding or rolling in the fluidizing bed, poor catalyst distribution, localized poor heat transfer, or areas of poor fluidization on the reactor distributor plate. Sheets and agglomerates interfere with fluidization and plug the product purge bin valve, requiring UCC to shut down and clean the reactors.

Another operability issue is the formation of small, dust-like particles called “fines”. Fines can create static (which

can lead to sheeting), cause continuity problems in the reactor, and foul the cycle gas system.

The occurrence of operability problems might require a reactor to be “killed”. A reactor kill (or CO kill) is typically accomplished by the injection of carbon monoxide into the reaction cycle gas to either reduce the rate of reaction (a minikill) or stop all reaction as quickly as possible.

PE material meeting all applicable product specifications is referred to as “aim-grade”. PE material that does not meet all applicable product specifications is referred to as “off-grade”. The production of off-grade material was not unusual, and UCC sold both aim-grade and off-grade resin to third parties but at different prices. Specific product properties of PE resins include the average particle size (APS), density (for solid molded resin), bulk density (for loose resin powder), film appearance rating (FAR), hexane extractables (relating to the stickiness of the resin), melt flow index, melt flow ratio (MFR), and resin morphology.

The specific properties of the PE products made in a UNIPOL reactor are determined by a variety of factors, including the catalyst used and reactor operating conditions. The key reactor operating conditions that determine the properties of the PE resin are reactor temperature, ethylene partial pressure,

hydrogen-to-ethylene ratio, comonomer ratio, TEAl cocatalyst ratio (Al/Ti), and residence time.

Star's reactors made a variety of PE base resins. UCC identified base resins using a three-letter prefix followed by a four-number code and either an "H" or a "B". The prefix of all base resins begins with a "D", followed by a "J" if UCAT-J is used as the catalyst or a "G" if M-1 is used as the catalyst, followed by an "H", "M", or "L" depending on the melt index range. The four-number code identifies the density and melt index designation. The final "H" or "B" identifies the comonomer as hexene or butene, respectively.

A transition is the period when reactor conditions are changed from one product's specifications to a new product's specifications. A transition typically takes three to four bed turnovers to complete, and each bed turnover lasts about 2 hours. A bed turnover is the average amount of time material stays in the reactor before flowing out of the product stream. The resin made during transitions is either intermediate-grade material that can be recycled into aim-grade resin or off-grade material sold for scrap uses such as picnic tables and barrels. Once a reactor is transitioned into a new product it takes a number of additional bed turnovers to "line out" the reactor. Lining out the reactor involves increasing the production rate back to the normal level after slowing down for the transition and returning

operation conditions back to their normal steady state. After a transition from M-1 to UCAT-J, it takes at least 12 hours to line out the reactor.

2. UCAT-J

In a chemical reaction, a catalyst is a substance that increases the rate of the reaction or causes the reaction to occur under different conditions than otherwise possible. Polymerization cannot occur in a UNIPOL reactor without a catalyst. The catalyst provides the site on which the polymer chain grows. A PE catalyst “precursor” refers to the catalyst state before the incorporation of aluminum alkyl catalyst modifying agents.

From Star’s startup in 1981 through the beginning of the UCAT-J runs at Star in 1992, Reactor 1 and Reactor 2 at the LP-3 unit operated exclusively on a catalyst called M-1. UCC continued to use M-1 at Star during the credit years during normal production runs occurring between UCAT-J runs. Despite its extensive experience using M-1, UCC occasionally experienced operability and continuity problems with M-1, particularly sheeting.

UCC developed UCAT-J as a superior catalyst alternative to M-1. The primary advantage of UCAT-J is that UCAT-J is over four times more “active” than M-1, meaning that the same amount of catalyst makes over four times as much PE resin as can be made

with M-1. This, in turn, significantly reduces both capital outlays for catalyst manufacturing facilities and the cost of catalysts used in manufacturing PE. UCAT-J also requires less hydrogen and TEAl than M-1, thereby reducing manufacturing costs further, and improves some properties of PE resin such as FAR. However, UCC used about the same amount of ethylene, hexene, and butene regardless of whether it used M-1 or UCAT-J. Although UCC had not commercialized UCAT-J during the credit years, UCC knew of these advantages during the credit years and described them to its licensees in anticipation of UCAT-J's commercialization.

M-1 and UCAT-J are both Ziegler-Natta catalysts, a general category of PE catalysts made from a transition metal such as titanium and requiring a cocatalyst to initiate polymerization. Both catalysts are based on a chemical solution of magnesium chloride, titanium trichloride, and tetrahydrofuran, although the proportions of these materials in M-1 and UCAT-J are different. Most significantly, UCAT-J has a higher titanium loading and magnesium-to-titanium ratio than M-1, both of which give UCAT-J superior activity. Both M-1 and UCAT-J use titanium to provide the catalyst active site and TEAl as the co-catalyst.

To create M-1, a chemical solution is added to small particles of treated silica, which absorb the solution. Most of the tetrahydrofuran is then evaporated to produce a free-flowing solid, which is the M-1 precursor. The M-1 precursor is then

reduced with aluminum alkyls, diethylaluminum chloride (DEAC) and tri-n-hexylaluminum (TnHAl), to produce the M-1 catalyst. Catalyst reduction refers to the treatment of the catalyst precursor with aluminum alkyl modifying agents to moderate catalyst activity and ensure acceptable product properties such as bulk density and particle size. The aluminum alkyl reduction agents used for both M-1 and UCAT-J were DEAC and TnHAl. In its final form, M-1 is a dry powder resembling sand.

UCAT-J is spray dried instead of being silica based. The chemical solution is transformed into a fine droplet spray in a spray dryer. As these droplets pass through a drying chamber, the tetrahydrofuran evaporates, leaving only the solid catalyst. The catalyst is then added to mineral oil to create a slurry (a mixture of liquid and insoluble solids) of UCAT-J precursor. The UCAT-J precursor is then reduced with aluminum alkyls. Although Star made its own M-1 catalyst precursor, UCC made UCAT-J precursor at a separate catalyst manufacturing facility in South Charleston and shipped it to Star.

Because of the different methods by which they are made, M-1 and UCAT-J have different “catalyst morphology”, a term used to describe the size, shape, and surface texture of a catalyst particle. M-1 catalyst particles have a substantially larger APS than those of UCAT-J. M-1 particles are typically rounder and smoother than UCAT-J particles. UCAT-J’s morphology creates some

problems that were not present with M-1, particularly increased fines and resin flowablity problems. These problems created operating uncertainties that had not been resolved by the beginning of 1994. UCAT-J and M-1 also respond differently to other chemicals present during polymerization, respond differently to reactor conditions, and create differences in PE product properties.

M-1 precursor is reduced in the catalyst manufacturing unit before the catalyst is delivered for use in the reactor. UCAT-J precursor, in contrast, requires “in-line” catalyst reduction, meaning that the DEAC and TnHAl modifying agents are injected into the catalyst stream immediately before it is fed into the UNIPOL reactor.

Before the first UCAT-J run at Star, which occurred in May 1992, UCC installed new equipment at Star to allow the in-line reduction of UCAT-J precursor. The in-line precursor modification system was a new unit operation installed specifically for use with UCAT-J. In this system, UCAT-J precursor was placed into a slurry feed tank, agitated to maintain good dispersion, and pumped at a controlled rate. DEAC and TnHAl were pumped into the catalyst stream at a specific ratio to the catalyst feed. Following the injection of the aluminum alkyls, the precursor flowed into a static mixer to

ensure adequate contacting and then into a residence time pot to provide time for the in-line modification to occur.

The UCAT-J in-line reduction system presented several operating uncertainties not present with M-1. When the system was first used, it created catalyst consistency problem that were due in part to the absence of static mixers and in part to the fact that the original design contacted the UCAT-J precursor with DEAC first and then with TnHAl, as was customary with M-1. UCC later discovered that consistency improved when the order was reversed. UCC also had difficulty controlling flow rates, keeping control consistent and accurate, and injecting UCAT-J because a slurry does not disburse as easily as a dry catalyst like M-1. These uncertainties were not resolved by 1994.

3. Overview of the UCAT-J Project

The UCAT-J commercialization program involved the development of UCAT-J to the point where it could be commercialized. UCC's UNIPOL licensing business wanted to commercialize UCAT-J in order to: (1) Derive revenues from selling UCAT-J to existing UNIPOL licensees; (2) be able to tout the superior qualifies of UCAT-J to prospective UNIPOL licensees; (3) avoid the capital costs associated with constructing plants to manufacture the less-productive M-1 catalyst; and (4) reduce Star's manufacturing costs as a result of UCAT-J's superior productivity. The UCAT-J commercialization program took place at

Star from 1992 to 1996. References to the "UCAT-J project" are only to those runs that occurred during the credit years.

Once UCC made the decision to commercialize UCAT-J, members from process R&D, product R&D, and catalyst R&D formed an interdisciplinary UCAT-J technology task force. The members met monthly or bimonthly, usually in person, to review the status of the commercialization effort and develop strategies for overcoming problems with UCAT-J implementation.

During 1993 through 1995 UCC's process R&D group conducted what it called "experimental runs" of UCAT-J on a small-scale UNIPOL reactor at a pilot plant at the South Charleston technical center. UCC defined an experimental run as a run of a product that UCC deemed noncommercial.[14] During the credit years UCC's manufacturing business required that a commercial facility conduct at least two, but preferably three, objective-meeting experimental runs of new PE products, including products made with a new catalyst, for the products to be considered commercial. The successful completion of two to three objective-meeting runs would demonstrate the operability of a new technology to the satisfaction of the UNIPOL R&D and manufacturing organizations. A customer's qualification of a PE resin depended on an independent inquiry related to the

[14]We use the term "experimental run" for convenience and consistency with UCC's terminology.

suitability of the product produced and did not establish that the product could be produced consistently enough to be considered commercial. UCC was not required to advise customers that they were receiving base resins produced with UCAT-J unless a specific contractual term required such a disclosure.

The South Charleston pilot plant's UNIPOL reactors were used strictly for R&D purposes, and one reactor was dedicated to UCAT-J. UCC ran UCAT-J on the pilot plant reactor to evaluate catalyst performance, estimate optimal operating conditions for the commercial reactors, and make PE resin for evaluation by the product R&D group in Bound Brook. After experimenting with new technologies on the pilot plant, UCC generally experimented with the technologies on its mid-size UNIPOL reactors at Seadrift before experimenting with the technology on the larger reactors at Star. However, UCC took some UCAT-J products from the pilot plant directly to Star or did not test them on smaller reactors at all.

Successful commercialization of UCAT-J required UCC to conduct experimental runs at UCC's commercial plants to evaluate whether UCAT-J could be used with reactor operability and resin properties at least equivalent to, and hopefully better than, those achieved using M-1. While UCC was often able to achieve at least the same level of reactor operability and continuity using UCAT-J as it had achieved with M-1 at pilot plants, commercial-

scale plant tests were also necessary because there were significant differences between the pilot plants and commercial reactors. For example, the bed volume of Star's commercial reactors was about 825 times the size of the bed volume of the pilot plant reactor. Because of this difference, UCC's pilot plant and commercial reactors use different methods of fluidization. These differences affect the amount of sheeting and static in a reactor. Accordingly, a successful run at the pilot plant did not indicate that sheeting and static would not cause significant problems when a similar run was conducted at a commercial plant.

The first commercial-scale run using UCAT-J was conducted on UCC's smallest commercial-scale reactor, the G-1750 reactor at Seadrift, in 1991. UCC continued the UCAT-J commercialization program at Star until 1996. UCC did not consider UCAT-J fully commercial before the program was completed because UCC did not know with certainty how UCAT-J would affect reactor operability and continuity, how it would affect product quality and how much off-grade material it would produce, whether there would be problems feeding the catalyst into the reactor, and how it would respond to CO kills. UCC was also concerned about reactor feed stability, fines creation, production rate control, resin properties, sheeting, and agglomeration. Such reactor operability and continuity issues could develop at any time

during an experimental run, so process R&D representatives remained on site for the duration of the runs, even after the reactor had been successfully transitioned into UCAT-J. Process R&D preferred longer experimental runs because they afforded more opportunities to evaluate reactor operability and continuity.

UCAT-J experimental runs were initiated by the completion of an experimental run request by the appropriate business manager, R&D group leader, inventory planning and control (IPAC) manager, and plant department head. IPAC controlled the scheduling of the experimental runs and the duration of each run. When scheduling the runs, IPAC considered existing customer orders and the risks posed by experimental runs so that the experimental runs would fit UCC’s commercial requirements. Once an experimental run request was completed and the experimental run was scheduled, representatives from process R&D in South Charleston would prepare a strategic run plan with input from the UCAT-J technology task force. The principal purpose of a strategic run plan was to communicate to all interested parties the run objectives, key operating parameters, analytical requirements, and run coverage. After receiving the strategic run plan, a Star engineer would prepare a tactical run plan. The purpose of the tactical run plan was to give detailed run instructions to the plant operators responsible for reactor operation. Strategic run plans and tactical run plans were not prepared for routine

commercial production runs. The operations improvement group would also complete a “New Product Introduction/Commercialization Procedure Checklist” showing whether all required documentation was in place.

The function of process R&D representatives during experimental runs was to evaluate what was happening in the reactor, identify problems, create hypotheses for how to solve those issues or improve the process, and test those hypotheses by conducting experiments. Process R&D representatives conducted experiments by adjusting operating ratios, modifying catalyst properties, and introducing new reactor control technologies. Process R&D generally did not address minor problems that could be solved by troubleshooting, which were addressed by the production group at the plant.

During the UCAT-J project process R&D regularly collected various measurements of reactor operability and continuity and product properties. While many of these measurements were collected during nonexperimental runs, process R&D representatives collected some data that were not normally collected and took other measurements more frequently than they normally would. For example, process R&D measured residual aluminum and titanium to monitor for TEAl starvation during the UCAT-J project but did not normally take these measurements. TEAl starvation occurs when there is an inadequate amount of TEAl

cocatalyst in the reactor. This lowers hydrogen and comonomer response and catalyst productivity, which cause a loss of control over the reactor and product properties. Process R&D also measured hexane extractables more frequently than normal during the UCAT-J project. The process R&D representatives recorded their observations in R&D notebooks. At least every other day process R&D sent an e-mail update to the members of the UCAT-J technology task force and UCC's management. This was not done for normal commercial production runs. Process R&D representatives were also called upon to address significant production problems with products made using the M-1 catalyst during the credit years.

Representatives from catalyst R&D and product R&D, both based in Bound Brook, were available as needed. Samples of PE resins made during UCAT-J experimental runs were shipped to the product R&D group for testing to ensure that the resin was equivalent to or better than that made with M-1. Any remaining aim-grade resin made during the experimental runs was sold to UCC's customers. Product R&D did not provide coverage or test resin samples for routine commercial production runs with M-1.

The run team, comprising representatives from process R&D and Star's management and operations staff, met before each run to discuss the run objectives and transition into UCAT-J. The run team also met regularly during the course of the UCAT-J runs

to assess the status of the run objectives and develop strategies for resolving any operating problems that had surfaced. At the end of each run the run team met to discuss the extent to which the run objectives had been met. The run team presented these findings at meetings of the UCAT-J technology task force. In addition, process R&D representatives prepared a run notebook for each run containing the strategic run plan, the tactical run plan, the R&D monthly report description of the run, the presentation to the UCAT-J technology task force, e-mails and other communications regarding the run, and lab data. Process R&D also described the UCAT-J runs in monthly reports issued by the process R&D group, but these reports did not provide technical details concerning the runs. Process R&D did not generally mention normal production runs in these reports.

4. Experimental Runs Before the Credit Years

UCC conducted nine UCAT-J run campaigns on reactor 2 at Star from May 1992 to November 1993. The UCAT-J runs conducted at Star in 1992 and 1993 involved only hexene LLDPE film resins made on reactor 2. These were the principal products made at Star and UNIPOL licensee plants and tended to have tighter product requirements than molding resins. At the end of 1993 UCC had conducted no UCAT-J runs on reactor 1 or on reactor 2 with either molding or butene film resins.

About 6 percent of the PE resin UCC made at Star in 1993 was made with UCAT-J. By the end of 1993, UCC had resolved some uncertainties related to UCAT-J such as an issue related to catalyst particle size. The plant personnel at Star also gained experience operating the plants using UCAT-J and were at ease using UCAT-J and in transitions. Furthermore, a number of UCAT-J runs had produced no off-grade product.

However, the UCAT-J runs conducted at Star in 1992 and 1993 suffered from numerous operability problems. Many were unresolved as of the end of 1993, including: (1) Gas channeling (resin becomes stagnant and nitrogen is channeled through the resin instead of mixing with it, causing inadequate resin purging); (2) TEAl starvation; (3) sticky stretch LLDPE resins (resins that agglomerated and did not flow properly); (4) sheeting; and (5) poor control over product properties such as melt index, density, and hexane extractables caused by differences in UCAT-J and M-1 catalyst morphology. UCC was confident that many of these issues could be resolved but was unsure when or how it would be able to resolve them.

Following a UCAT-J run campaign on LLDPE film resins in November 1993, a moratorium was imposed on further experimental runs on film resins to allow R&D to work out various problems, some related to UCAT-J and others that were general plant

problems. UCC did not believe that UCAT-J was ready to be commercialized by the end of 1993.

5. Experimental Runs During the Credit Years

At the beginning of 1994 some of the major outstanding issues with UCAT-J were: (1) Obtaining acceptable product properties in fractional melt index film resins; (2) resolving butene film bulk density problems; (3) determining the cause of and preventing resin stickiness; (4) establishing operating parameters for UCAT-J film resins; (5) developing UCAT-J for molding resins; and (6) ensuring that UCAT-J met operational requirements. UCC believed it needed to conduct additional experimental runs to resolve these issues.

UCC seeks research credits for the expenses incurred in 19 UCAT-J runs (UCAT-J runs 1 through 19) conducted at Star during the credit years. The base resins produced, types of resin produced (low-density film or high-density molding), start and end dates of the runs, and pounds of base resin produced according to UCC's product cost detail reports (PCDs) are included in the chart below:

Run No.	Base Resin	Resin Type	Start Date	End Date	Aim-Grade Resin Produced (pounds)	Off-Grade Resin Produced (pounds)
1	DJM-5265H	HDPE Molding	2/16/94	2/17/94	958,968	-
2	DJM-1810B	LLDPE Film	10/22/94	10/26/94	4,832,092	771,350
3	DJM-1732H	LLDPE Film	11/14/94	11/15/94	[1]188,068	[2]1,162,650
4	DJM-2419H	LLDPE Film	12/11/94	12/13/94	1,632,872	765,700
5	DJM-1810H	LLDPE Film	12/13/94	12/17/94	5,254,885	455,700
6	DJM-2016H	LLDPE Film	12/17/94	12/18/94	703,691	-
7	DJM-1725H	LLDPE Film	12/18/94	12/18/94	[3]731,842	[4]137,100
8	DJL-5264H	HDPE Molding	1/26/95	1/27/95	6,135,634	797,750
9	DJL-5280H	HDPE Molding	1/27/95	1/28/95	1,864,465	-
10	DJH-2580H	LLDPE Film	3/3/95	3/6/95	2,601,861	578,450
11	DJM-1810B	LLDPE Film	3/4/95	3/13/95	8,707,791	1,058,450
12	DJH-2950H	LLDPE Film	3/6/95	3/6/95	132,324	148,750
13	DJL-5420H	HDPE Molding	3/25/95	3/26/95	696,181	-
14	DJL-5143H	HDPE Molding	3/26/95	3/27/95	1,006,947	-
15	DJM-1732H	LLDPE Film	5/16/95	5/22/95	[5]4,091,446	[6]2,430,700
16	DJM-1725H	LLDPE Film	5/22/95	5/26/95	3,653,813	966,350
17	DJM-1720H	LLDPE Film	5/26/95	5/27/95	886,625	520,100
19	DJL-5280H	HDPE Molding	6/22/95	6/23/95	[8]	

[1]This amount was found on a PCD for DJM-1734H. UCC could not find a PCD for DJM-1732H, so it used the PCD for a similar product.

[2]This amount was found on a PCD for DJM-1734H. UCC could not find a PCD for DJM-1732H, so it used the PCD for a similar product.

[3]This amount includes base resin produced during both run 7 and another experimental run that took place in November 1994.

[4]This amount includes base resin produced during both run 7 and another experimental run that took place in November 1994.

[5]This amount was found on a PCD for DJM-1734H. UCC could not find a PCD for DJM-1732H, so it used the PCD for a similar product.

[6]This amount was found on a PCD for DJM-1734H. UCC could not find a PCD for DJM-1732H, so it used the PCD for a similar product.

[7]The resin that petitioner claims UCC produced during run 18 is included in the amount of resin petitioner claims UCC produced during run 8.

[8]The resin that petitioner claims UCC produced during run 19 is included in the amount of resin petitioner claims UCC produced during run 9.

a. DJM-5265H (UCAT-J Run 1)

UCAT-J run 1 was the first UCAT-J run at Star with a molding resin and the first UCAT-J run conducted on reactor 1. The base resin, DJM-5265H, was selected to be the first molding resin made with UCAT-J at Star because it was a basic cornerstone product that Star made in large quantities and UCC considered it to be a low-risk product. UCC had made aim-grade DJM-5265H at the pilot plant using UCAT-J and found UCAT-J to be equivalent to M-1 with respect to operability and continuity on that scale.

Before UCAT-J run 1, two short runs of DJM-5265H had been conducted at the UNIPOL facility of a licensee, Hanwa Chemical Corp. (Hanwa), in Korea. While the runs at Hanwa were generally successful, they lasted only a few days, and the second run was aborted when the second transition failed. These results were of limited value to UCC because Hanwa's reactors were different from Star's reactors. Hanwa's reactors were just over half the size of Star's reactors and so were less prone to static. Furthermore, Hanwa's reactors had a purification system for raw materials that was considerably better than UCC's purification

system. As a result, Hanwa's reactor feed was much cleaner than UCC's and the catalyst had better productivity.

The objectives of UCAT-J run 1 were to: (1) Successfully scale up production (adjust production to take into account the differences in reactor size) of DJM-5265H from the South Charleston pilot plant to reactor 1; (2) produce aim-grade resin for customer qualification; and (3) establish reactor operability and continuity on reactor 1. As to the third objective, UCC was not merely confirming that reactor operability and continuity were as expected. UCC wanted to evaluate how well reactor 1 worked with UCAT-J.

UCC's primary concerns before UCAT-J run 1 were that: (1) The differences between the pilot plant and reactor 1 at Star could cause the product to go off grade; (2) TEAl starvation could cause operability and continuity problems; (3) difficulties with CO kills could occur if any kills were necessary; and (4) resin clumpiness could cause operability and continuity problems.

As with all of the UCAT-J runs discussed below (although not specifically mentioned below for brevity), representatives from process R&D and product R&D provided coverage for UCAT-J run 1 and process R&D collected data, some of which were not normally collected or was not normally collected as frequently. Additionally, samples of resin were collected during and

following the run and were sent to product R&D in Bound Brook for evaluation.

UCAT-J run 1 was aborted after 17 hours because of sheeting caused by the use of M-1 before the transition to UCAT-J and the formation of a spongy material that resembled Styrofoam. UCC analyzed the spongy material and determined that it formed because of the use of UCAT-J. But because the sheeting was caused by M-1, UCC was unable to determine the extent to which the use of UCAT-J contributed to the shutdown.

UCC also discovered a discrepancy between the Ti/Al ratio calculated by flow rate and the measured Ti/Al ratio that correlated with catalyst feed rate. UCC was unable to explain this discrepancy and was concerned about TEAl starvation. UCC also discovered more fines than expected.

UCAT-J run 1 did not last long enough for UCC to draw any conclusions from the run. It remained uncertain following the run whether UCAT-J could be used on reactor 1 with operability, continuity, and resin properties equivalent to those achievable with M-1. Because of the formation of the spongy material, TEAl starvation concerns, and increased fines, UCC had serious doubts as to its ability to make further product. Therefore, it did not attempt to make another molding resin run again until 1995.

According to a PCD for DJM-5265H, UCC produced 958,968 pounds of aim-grade base resin for customer evaluation during

UCAT-J run 1.[15] Petitioner claims as QREs costs associated with producing 960,150 pounds of aim-grade base resin during UCAT-J run 1.

b. DJM-1810B (UCAT-J Runs 2 and 11)

UCAT-J run 2 was the first UCAT-J run conducted at Star using butene, as opposed to hexene, as the comonomer. UCC wanted its plant operators to gain production experience using butene comonomers in anticipation of the startup of LP-6. There had been successful runs of DJM-1810B at Seadrift, the pilot plant, and a licensee's facility, which encouraged UCC to believe that it would be able to use butene as a comonomer at Star. However, process R&D had encountered significant difficulties producing butene film resins using UCAT-J with acceptable bulk density because of particle morphology differences between UCAT-J and M-1.

The principal objective for UCAT-J run 2 was to successfully scale up UCAT-J on the butene film resin from the pilot plant to Star. A successful scale-up would require that the run: (1) Demonstrate operability using UCAT-J equivalent to that achievable using M-1; (2) reach aim-grade production within a

[15]As discussed below, PCDs were produced monthly and annually, not for specific projects. However, no base resin produced with UCAT-J was made in more than one run in any given month during the credit years. Accordingly, the PCD for the month in which a UCAT-J run occurred would include information only for that particular run.

specified period; (3) produce no significant off-grade material once the transition was complete; and (4) produce resin with acceptable bulk density. UCC was uncertain before the run whether any of these requirements would be met or whether the scale-up would be successful. UCC also hoped to produce 10 to 12 million pounds of aim-grade resin to sell to customers during UCAT-J run 2.

To achieve acceptable bulk density, process R&D planned to change the catalyst reduction ratios and increase the amount of isopentane in the reactor during the run. Process R&D regarded both changes as experimental and was uncertain whether they would improve bulk density without adversely affecting reactor productivity.

Additional objectives of UCAT-J run 2 were to demonstrate a closed reactor restart with UCAT-J following a CO kill on M-1 and to demonstrate the ability to kill the reactor while it contained UCAT-J. UCC had never attempted a closed reactor restart at Star with UCAT-J. UCC had had some experience with CO kills using UCAT-J, but the results had been mixed. In particular, mini-kills had been much less effective when using UCAT-J as compared with M-1.

UCC was also concerned about several other risks, including: (1) TEAl starvation; (2) resin carryover (a negative effect of

low resin APS, which may result from steps taken to improve bulk density); and (3) resin clumpiness.

UCAT-J Run 2 began well and met some of the objectives, including the first successful reactor startup with UCAT-J, no significant off-grade material produced, and unexpectedly high bulk density. However, UCC experienced operating problems a few days into the run that required the reactor to be shut down and the run aborted. The most significant of these problems were unexplained production rate swings and the formation of “cue balls” of PE resin that were about the size of softballs. UCC hypothesized that the cause of the cue balls was poor catalyst dispersion, and accordingly it planned to change the injection tube for the next run of DJM-1810B to improve catalyst dispersion and determine whether that would solve the problem.

According to a PCD for DJM-1810B, UCC produced 4,832,092 pounds of aim-grade and 771,350 pounds of off-grade base resin during UCAT-J run 2. Petitioner claims as QREs costs associated with producing 4,954,150 pounds of aim-grade and 771,350 pounds of off-grade base resin during UCAT-J run 2.

UCAT-J run 11 was the second run of DJM-1810B. UCC’s primary objective was to make DJM-1810B without the problems experienced in UCAT-J run 2.

UCAT-J run 11 lasted from March 4 to 13, 1995, the longest run for a single product during the UCAT-J project. A long run

is usually evidence that the run was successful. However, the transition to DJM-1810B was unusually long and difficult, and a significant amount of off-grade resin was produced. Once UCAT-J was introduced into the reactor, the resin bulk density unexpectedly dropped significantly, causing the product purge bin to plug. This resulted in significant off-grade material and required the production rate to be lowered. UCC did not anticipate the bulk density problem because UCAT-J run 2 produced resin with unexpectedly high bulk density. There were also problems with catalyst stability, sheeting, poor hydrogen control, and melt index swings. These problems were all specific to UCAT-J and were not anticipated before the run.

Because of the bulk density and operability problems, UCC decided to return the testing of DJM-1810B to Seadrift. While UCAT-J run 11 provided valuable operating data, it did not establish that reactor 1 at Star could produce UCAT-J butene LLDPE film resins with operability and continuity equivalent to that achieved using M-1.

According to a PCD for DJM-1810B, UCC produced 8,707,791 pounds of aim-grade and 1,058,450 pounds of off-grade base resin during UCAT-J run 11. Petitioner claims as QREs costs associated with producing 8,941,350 pounds of aim-grade and 1,058,450 pounds of off-grade base resin during UCAT-J run 11.

c. DJM-1732H (UCAT-J Runs 3 and 15)

UCAT-J run 3 produced DJM-1732H, a low-density, high-melt-index LLDPE film resin. UCAT-J run 3 was the first UCAT-J experimental run of an LLDPE film resin with a hexene comonomer conducted at Star since November 1993. UCC experienced so many problems during the November 1993 run and the run had such a negative impact on manufacturing that R&D wanted to do more work on smaller reactors before attempting the run again at Star. UCC had conducted runs of DJM-1732H at Star in January and March 1993 for 1 day each, but these runs were too short to establish that the process could be used with sufficient operability and continuity.

The objectives of UCAT-J run 3 were to: (1) Produce sufficient product for customer qualification; (2) run reactor 2 at normal Star rates with operability and continuity equivalent to or better than M-1; (3) reach aim-grade production within a specified period; and (4) produce no significant off-grade material. UCC was uncertain whether any of these objectives could be met or whether the run would be successful.

Because low-density, high-melt-index LLDPE film resin is sticky by design, resin flowability was a primary concern before UCAT-J run 3. UCC was also concerned about: (1) TEAl starvation; (2) resin carryover; (3) difficulties with CO kills, if they were necessary; and (4) resin clumpiness. Resin

clumpiness had also been a problem when using M-1 to make DJM-1732H but tended to be worse with UCAT-J.

UCAT-J run 3 had several successes: (1) UCC was able to use CO mini-kills, which produced a rapid and significant effect; (2) no fines were produced; and (3) a hopper car of resin was produced. However, the run as a whole was considered a failure and several problems occurred: (1) There was extensive formation of clumpy resin that plugged the product purge bin; (2) there was poor melt index control; and (3) there was TEAl starvation in the reactor. Process R&D evaluated these problems, identified their potential causes, and developed possible solutions for future runs. UCC determined that the next run might be more successful if it: (1) Lowered the ethylene partial pressure in the reactor to reduce the amount of hexane; (2) controlled the cycle gas composition and flow ratio; and (3) doubled the TEAl feed into the reactor for 20 minutes (known as giving the reactor a “TEAl shot”) periodically even if starvation was not expected and more frequently during upset conditions. UCAT-J run 3 did not establish that UCAT-J could be used with operability and continuity equivalent to that achieved using M-1.

According to a PCD for DJM-1734H, not DJM-1732H, UCC produced 188,068 pounds of aim-grade and 1,162,650 pounds of off-grade DJM-1734H in 1994. No PCD was available for DJM-1723H for 1994. Petitioner claims as QREs costs associated with producing

188,850 pounds of aim-grade and 1,162,650 pounds of off-grade base resin during UCAT-J run 3. However, other postrun documentation indicates that UCC produced 743,987 pounds of aim-grade base resin during UCAT-J run 3.

In addition to the objectives stated for UCAT-J run 3, a goal of UCAT-J run 15, the next run of DJM-1732H, was to implement measures developed by process R&D to control resin stickiness and TEAl levels and to demonstrate acceptable operability and continuity using UCAT-J in reactor 2. To control resin stickiness, process R&D recommended that ethylene partial pressure be lowered below 90 psi, which had never been done before at Star with UCAT-J. This change to reactor conditions was considered experimental and had two drawbacks: (1) Lowering the ethylene partial pressure could lower the productivity of the catalyst, which would lower resin APS and increase fines, causing fouling; and (2) if the reactor transitioned back to M-1, it would be necessary to increase the ethylene partial pressure by a greater amount. UCC also planned to give the reactor periodic TEAl shots to minimize TEAl starvation, which UCC began using in run 4 (discussed below). However, UCC was unsure whether these steps would be successful.

UCC hoped to produce 23 hopper cars of DJM-1732H for customer qualification and consumption. Other run objectives were to: (1) Run reactor 2 at normal production rates; (2) reach

aim-grade production within a specified period; and (3) produce no significant off-grade material.

UCAT-J run 15 was generally successful. UCC was able to control resin stickiness by lowering the ethylene partial pressure, and UCC was able to maintain good catalyst productivity even though it is more difficult to maintain at low ethylene partial pressure. Overall, operability and continuity were good throughout the run. However, while flowability improved, it was still slightly worse than flowability that had been achieved using M-1. Furthermore, there was some TEAl starvation due to the TEAl feed system, though less than had occurred during previous runs. Therefore, the information gained was valuable to UCC but process R&D still had some concerns.

A PCD for DJM-1734H, not DJM-1732H, shows that UCC produced 4,091,446 pounds of aim-grade DJM-1734H in 1995. No PCD was available for DJM-1732H for 1995. Petitioner claimed as QREs costs associated with producing 4,108,850 pounds of aim-grade and 2,430,700 pounds of off-grade base resin during UCAT-J run 15.

d. DJM-2419H, DJM-1810H, and DJM 2016H (UCAT-J Runs 4 Through 6)

UCAT-J runs 4 through 6 were all runs of hexene LLDPE film resins. With the exception of DJM-1810H (UCAT-J run 5), which had been used as an experimental bed resin for various types of reactor testing, Star had limited experience with the UCAT-J resins to be made in these runs.

UCC designed UCAT-J run 4 to make DJM-2419H, which UCC had previously made at Star only during a 1-day run in 1993. UCC produced approximately 600,000 pounds of DJM-2419H in 1993 and UCC's customers had accepted DJM-2419H made with UCAT-J. However, UCC was still uncertain whether it would be able to produce DJM-2419H at Star consistently with satisfactory operability.

UCC designed UCAT-J run 5 to make DJM-1810H. UCC had used DJM-1810H as an experimental bed resin and had produced it in 11 runs at Star during 1992 and 1993. UCC experienced significant problems during the earlier runs. During the later runs UCC used DJM-1810H as an experimental bed for catalyst reduction tests, order of reduction tests, and similar tests. UCC made about 170 hopper cars of DJM-1810H in 1993. DJM-1810H produced with UCAT-J had already been accepted by customers. However, UCC still considered DJM-1810H to be an experimental resin at this point, primarily because it had flowability problems.

UCC designed UCAT-J run 6 to produce DJM-2016H, which UCC had never made at Star. However, UCC had produced DJM-2016H at other plants during earlier experimental runs and customers had qualified resin produced during those runs. UCC expected results similar to those that had been obtained during runs of DJM-1810H (UCAT-J run 5).

The overarching goal of these runs was to demonstrate sustained operability of UCAT-J with hexene LLDPE film resins. The specific run objectives listed on the strategic run plan were to: (1) Produce sufficient product for customer qualification; (2) further commercial experience through the extended production run of DJM-2419H (UCAT-J run 4) and DJM-1810H (UCAT-J run 5) (among other runs not claimed); (3) run reactor 2 at normal Star rates with operability equivalent to that achieved using M-1; (4) reach aim-grade production within a specified period; and (5) produce no significant off-grade material outside product transitions.

In response to a recommendation made at the UCAT-J technology task force meeting following UCAT-J run 3, UCC decided to run reactor 2 at a lower than normal ethylene partial pressure during UCAT-J runs 4 through 6 to improve resin flowability. UCC considered this change to be an experiment because it was uncertain whether the change would successfully eliminate flowability problems and there was a risk that the change could significantly reduce catalyst productivity. UCC also decided to use production rate control, which is an automated system to control the catalyst feed rate and the ethylene partial pressure in the reactor. The goal of this system was to maximize production rate by allowing production rate to run closer to the constraints of the reactor system.

Because of the problems with TEAl starvation in UCAT-J run 3, UCC decided to experiment with TEAl shots during UCAT-J runs 4 through 6. However, UCC was concerned that increasing the Ti/Al ratio would also increase hexane extractables.

In addition to TEAl starvation, UCC identified several other risks related to UCAT-J runs 4 through 6: (1) Resin carryover; (2) difficulties with CO kills, if they were necessary; and (3) resin clumpiness.

Process R&D representatives evaluated the ethylene partial pressure and TEAl shot experiments during UCAT-J runs 4 through 6 in addition to the support that R&D provided to all of the UCAT-J runs.

UCAT-J runs 4 through 6 were generally successful. Reducing the ethylene partial pressure and using production rate control reduced the stickiness problem and giving the reactor TEAl shots reduced TEAl starvation. UCC viewed this as a substantial achievement. The only significant problem was a decrease in FAR, which occurs when there are gels or foreign matter in the film. UCC took samples of the resin to try to determine the potential causes and solutions for the decreased FAR. UCC hypothesized that the decrease in FAR was caused by the use of wet hexene.

Process R&D concluded that it had gained confidence that Star could produce DJM-1810H (UCAT-J run 5) and DJM-2016H (UCAT-J run 6) with sufficient operability and continuity. However, UCC

believed that additional experiments were necessary to reach this conclusion with respect to DJM-2419H (UCAT-J run 4).

According to a PCD for DJM-2419H, UCC produced 1,632,872 pounds of aim-grade and 765,700 pounds of off-grade base resin during UCAT-J run 4. Petitioner claims as QREs costs associated with producing 1,640,950 pounds of aim-grade and 765,700 pounds of off-grade base resin during UCAT-J run 4.

According to a PCD for DJM-1810H, UCC produced 5,254,885 pounds of aim-grade and 455,700 pounds of off-grade base resin during UCAT-J run 5. Petitioner claims as QREs costs associated with producing 5,270,050 pounds of aim-grade and 455,700 pounds of off-grade base resin during UCAT-J run 5.

According to a PCD for DJM-2016H, UCC produced 703,691 pounds of aim-grade base resin during UCAT-J run 6. Petitioner claims as QREs costs associated with producing 704,600 pounds of aim-grade base resin during UCAT-J run 6.

e. DJM-1735H (UCAT-J Runs 7 and 16)

UCAT-J run 7 was an experimental run of DJM-1725H, another hexene LLDPE film resin that is very sticky and had shown poor flowability. UCAT-J run 7 began and ended on December 18, 1994. UCC also produced DJM-1725H in November 1994, but there were so many problems with clumpy resin, melt index control, and TEAl starvation that UCC did not use that resin for customer qualification.

As in UCAT-J runs 4 through 6, the overarching objective of UCAT-J run 7 was to demonstrate sustained operability of UCAT-J with hexene LLDPE film resins. The specific run objectives were to: (1) Produce sufficient product for customer qualification; (2) run reactor 2 at normal Star rates with operability equivalent to that achieved with M-1; (3) reach aim-grade production within a specified period; and (4) produce no significant off-grade material outside of product transitions.

UCC implemented the recommendation of the UCAT-J technology task force to run reactor 2 at a lower than normal ethylene partial pressure to improve resin flowability. UCC also gave the reactor TEAl shots to reduce TEAl starvation but was still concerned that increasing the TEAl ratio would also increase hexane extractables. In addition to the support R&D provided to all of the UCAT-J runs, process R&D representatives evaluated the ethylene partial pressure and TEAl shots experiments.

UCAT-J run 7 was generally successful. The only significant problem was a decrease in FAR caused by gels or foreign matter in the film, which had also occurred during UCAT-J runs 4 through 6. UCC took samples of the resin to try to determine the potential causes and solutions for the decreased FAR. UCC believed that additional experiments were necessary to gain confidence that it could produce DJM-1725H with sufficient operability and continuity.

According to the summary report of the UCAT-J experimental runs conducted at Star, UCC produced 480,461 pounds of aim-grade and 177,821 pounds of off-grade base resin during UCAT-J run 7. According to a PCD for DJM-1725H, UCC produced 541,866 pounds of aim-grade and zero pounds of off-grade base resin. Petitioner claims as QREs costs associated with producing 737,200 pounds of aim-grade and 137,100 pounds of off-grade base resin, which includes total production for 1994 (both UCAT-J run 7 and the run that took place in November 1994).

UCC produced DJM-1725H again in UCAT-J run 16 because UCAT-J run 7 did not establish that DJM-1725H could be made without continuity problems during longer runs. TEAl starvation remained another significant operating issue.

In addition to the objectives for UCAT-J run 7, the goals of UCAT-J Run 16 were to implement measures developed by process R&D to control resin stickiness and TEAl levels and to demonstrate acceptable operability and continuity of UCAT-J in reactor 2. As in UCAT-J run 15, to control resin stickiness process R&D recommended that ethylene partial pressure be lowered below 90 psi. UCC also planned to use periodic TEAl shots to minimize TEAl starvation. However, UCC was unsure whether these steps would be successful.

UCAT-J run 16 was generally successful. UCC controlled resin stickiness by lowering the ethylene partial pressure below

90 psi, and UCC was able to maintain good catalyst productivity. Overall, operability and continuity were good throughout the run. However, while flowability improved, it was still slightly worse than the flowability that could be achieved using M-1. Furthermore, there was some TEAl starvation due to the TEAl feed system, though less than had occurred during previous runs. Therefore, the information gained was valuable to UCC but process R&D still had some concerns.

According to a PCD for DJM-1725H, UCC produced 3,653,813 pounds of aim-grade and 966,350 pounds of off-grade base resin during UCAT-J run 16. Petitioner claims as QREs costs associated with producing 3,665,150 pounds of aim-grade and 966,350 pounds of off-grade base resin during UCAT-J run 16.

f. DJL-5264H and DJL-5280H (UCAT-J Runs 8, 9, 18,and 19

UCAT-J runs 8 (DJL-5264H) and 9 (DJL-5280H) were the next experimental runs of HDPE molding resins after UCAT-J run 1, which UCC aborted before it could draw any meaningful conclusions. Following UCAT-J run 1, process R&D took a year to evaluate UCAT-J molding resins in the pilot plant before conducting another experimental run at Star. UCC determined that UCAT-J was equivalent to M-1 with respect to reactor operability and continuity when making DJL-5264H and DJL-5280H at its pilot plant, but UCC was still uncertain whether UCAT-J would perform as well at Star. UCC had not yet determined that it could make

DJL-5264H or DJL-5280H consistently on full-scale commercial reactors before UCAT-J runs 8 and 9.

The objectives of UCAT-J runs 8 and 9 were to: (1) Produce sufficient product for customer qualification; (2) run reactor 1 at normal Star rates with operability equivalent to that achieved using M-1; (3) reach aim-grade production within a specified period; and (4) produce no significant off-grade material.

The primary risks UCC identified for UCAT-J runs 8 and 9 were: (1) TEAl starvation; (2) resin carryover; and (3) difficulties with CO kills, if they were necessary. To reduce the risk of TEAl starvation, UCC measured aluminum and titanium during the run and gave the reactor periodic TEAl shots. Since TEAl starvation had not been a problem with M-1, these measurements were not taken during commercial runs using M-1. Although resin carryover was listed as a risk on the strategic run plan for UCAT-J runs 8 and 9, according to the strategic run plan UCC did not actually expect resin carryover to be a problem.

UCAT-J runs 8 and 9 were generally successful. Reactor 1 demonstrated acceptable operability and continuity and all other run objectives were met. There was some melt index variation (resin in some hopper cars had a higher melt index than the resin in others), but this was not significant problem. Some TEAl starvation also occurred, but it did not cause the resin to go off grade; and UCC determined that it could most likely fix the

problem by implementing a different TEAl system. Because UCAT-J runs 8 and 9 each lasted only 1 day, UCC did not have time to fully evaluate operability and continuity. However, the information UCC gained was valuable, and one or two more successful experimental runs would establish to UCC's satisfaction that the process was ready for commercialization.

UCAT-J runs 18 and 19 were the next experimental runs of DJL-5264H and DJL-5280H. The operability and continuity of reactor 1 in making these products remained uncertain before these runs, as only a few short HDPE molding resin runs had been conducted up to this point with mixed results.

The primary objectives of UCAT-J run 18 were to operate at normal Star rates with operability equivalent to that achieved using M-1 and to make a maximum of 250,000 pounds of off-grade material.

UCAT-J run 18 yielded 825,000 pounds of off-grade material, which indicated poor operability, particularly poor control of the resin properties in the reactor. There were also problems with the product purge bin, poor flowability, and poor melt index control. However, UCAT-J run 19 was generally successful.

According to a PCD for DJL-5264H, UCC produced 6,135,634 pounds of aim-grade and 797,750 pounds of off-grade base resin during 1995, including both UCAT-J runs 8 and 18. Postrun documentation indicates that UCC produced 933,000 pounds of aim-

grade base resin during run 8 and 5,313,000 pounds of aim-grade and 825,000 pounds of off-grade base resin during UCAT-J run 18. Petitioner claims as QREs costs associated with producing 6,143,300 pounds of aim-grade and 797,750 pounds of off-grade resin during UCAT-J runs 8 and 18 combined.

According to a PCD for DJL-5280H, UCC produced 1,864,465 pounds of aim-grade base resin in 1995, including both UCAT-J runs 9 and 19. Postrun documentation indicates that UCC produced 851,844 pounds and 1,331,804 pounds of aim-grade base resin during UCAT-J runs 9 and 19, respectively. Petitioner claims as QREs costs associated with producing 1,750,532 pounds of aim-grade base resin during UCAT-J runs 9 and 19 combined.

g. DJH-2580H and DJH-2950H (UCAT-J Runs 10 and 12)

UCC made DJH-2580H (UCAT-J run 10) in two short runs in 1992 and 1993. The run in 1993 produced about 17 hopper cars of base resin that customers accepted. However, the 1992 and 1993 runs of DJH-2580H presented significant operability problems. DJH-2950H (UCAT-J run 12) was a difficult product to run and had never been made at Star.

The primary objectives of UCAT-J runs 10 and 12 were to produce these resins with acceptable product properties, particularly fractional melt index, and to demonstrate acceptable reactor operability and continuity.

UCAT-J run 10 ran for 3 days and then transitioned to DJH-2950H (UCAT-J run 12). Significant sheeting problems developed after the transition. The reactor was mini-killed and restarted, but the sheeting continued and became worse. As a result, Reactor 2 had to be shut down so that the sheets could be physically removed with a suction truck and chainsaws. Opening the reactor to remove sheets exposes the reactor to oxygen and can cause problems in subsequent runs. As a result of the sheeting, UCC aborted the runs and reactor 2 was restarted with M-1 because resuming operation with UCAT-J was considered to be too risky in the light of UCC's overall business considerations. However, some aim-grade resin was produced during the runs and was sold to customers.

Process R&D suspected that the sheeting that first developed after the transition to DJH-2950H (UCAT-J run 12) was due to the high molecular weight of the DJH-2950H resin, and the sheeting that developed after the mini-kill was due to static. Because of the significant sheeting problems experienced during these runs, process R&D moved testing of DJH-2580H and DJH-2950 to Seadrift before returning the testing to Star. UCC imposed a moratorium restricting fractional melt index products from operation at Star.

According to a PCD for DJH-2580H, UCC produced 2,601,861 pound of aim-grade and 578,450 pounds of off-grade base resin

during UCAT-J run 10. Petitioner claims as QREs costs associated with producing 2,668,500 pounds of aim-grade and 578,450 pounds of off-grade base resin during UCAT-J run 10.

According to a PCD for DJH-2950H, UCC produced 132,324 pounds of aim-grade and 148,750 pounds of off-grade base resin during UCAT-J run 12. Petitioner claims as QREs costs associated with producing 132,800 pounds of aim-grade and 148,750 pounds of off-grade base resin during UCAT-J run 12.

h. DJL-5420H and DJL-5143H (UCAT-J Runs 13 and 14)

Although UCC had successfully produced high density molding base resins in the pilot plant using UCAT-J, it had never made DJL-5420H (UCAT-J run 13) or DJL-5143H (UCAT-J run 14) at Star before these runs.

UCC's objectives for UCAT-J runs 13 and 14 were to: (1) Produce requested quantities of each resin for customer qualification (about four hopper cars for each product); (2) run reactor 1 at normal Star rates with operability equivalent to that achieved using M-1; (3) reach aim-grade production within a specified period; and (4) produce no significant off-grade material.

UCC was concerned about the risks of: (1) TEAl starvation; (2) resin carryover; and (3) difficulties with CO kills, if they were necessary. UCC planned for both of these runs to be short because of the risk associated with UCAT-J.

Several operability issues occurred during the runs, particularly minor sheeting during UCAT-J run 13, cold bands after the transition to DJL-5143H, and the formation of spongy agglomerates. A cold band is an area where the reactor wall is cold and it indicates that there is enough static to cause resin to stick to the walls and create sheeting. The spongy agglomerates that formed were similar to the substances that formed during UCAT-J run 1.

Despite these problems, UCC considered the runs to be a success. However, because these were short runs, UCC would need to continue to evaluate the resins to determine whether continuity issues would arise on longer runs.

According to a PCD for DJH-5420H, UCC produced 696,181 pounds of aim-grade base resin during UCAT-J run 13. Petitioner claims as QREs costs associated with producing 696,981 pounds of base resin during UCAT-J run 13.

According to a PCD for DJL-5143H, UCC produced 1,006,947 pounds of aim-grade base resin during UCAT-J run 14. Petitioner claims as QREs costs associated with producing 1,008,181 pounds of aim-grade base resin during UCAT-J run 14.

i. DJM-1720H (UCAT-J Run 17)

DJM-1720H had never been made at Star before UCAT-J run 17. Two of the goals of this run were to implement measures developed by process R&D to control resin stickiness and TEAl levels (first

implemented in UCAT-J runs 15 and 16, discussed above) and to demonstrate acceptable operability and continuity of UCAT-J in reactor 2 with these products. The other run objectives identified in pre-run documentation were to: (1) Produce the requested quantities of resin for customer qualification (four hopper cars); (2) run reactor 2 at normal production rates; (3) reach aim-grade production within a specified period; and (4) produce no significant off-grade material attributable to UCAT-J.

DJM-1720H is an LLDPE resin, which tends to be very sticky and had shown poor flowability in previous runs. TEAl starvation remained another significant operating issue. As in UCAT-J runs 15 and 16, to control resin stickiness process R&D recommended that ethylene partial pressure be lowered below 90 psi. UCC still considered this change to reactor conditions to be experimental. UCC also planned to give the reactor periodic TEAl shots to minimize TEAl starvation.

UCAT-J run 17 was generally successful. UCC controlled resin stickiness through ethylene partial pressure, and UCC was able to maintain good catalyst productivity. Overall, operability and continuity were good throughout the run. However, while flowability improved, it was still slightly worse than the flowability achieved using M-1. Furthermore, there was some TEAl starvation due to the TEAl feed system, though less than during previous runs. Therefore, the information gained was

valuable to UCC, but process R&D still had some concerns. Following UCAT-J runs 16 and 17 UCC planned to implement a new TEAl feed system for all of Star. Ultimately this alleviated the TEAl starvation issues.

According to a PCD for DJM-1720H, UCC produced 866,625 pounds of aim-grade and 520,100 pounds of off-grade base resin during UCAT-J run 17. Petitioner claims as QREs the costs associated with producing 895,700 pounds of aim-grade and 520,800 pounds of off-grade base resin.

III. Claimed Costs

One of petitioner's expert witnesses, Wendi Hinojosa,[16] was responsible for costing the claim projects. Ms. Hinojosa was qualified as an expert in the accounting systems and documentation used by UCC in the credit years and the base period. Petitioner claims as QREs incurred by UCC in connection with the claim projects $23,356,600 for 1994 and $32,114,800 for 1995.

A. Cost Documentation Used

1. PCDs and MASs

The primary cost accounting records that Ms. Hinojosa used to calculate the cost of the supplies used in the claim projects were PCDs and material accounting summary reports (MASs). PCDs

[16]Ms. Hinojosa's qualifications are set out in the Opinion section, below.

and MASs were part of UCC's material accounting system used to track variable costs (costs that vary with production) such as raw materials, catalysts, and other materials used in the manufacturing process. UCC used the material accounting system during both the credit years and the base period. There were no significant differences in UCC's material accounting system and related documentation during these two timeframes.

The PCD was UCC's official cost accounting record for products that it manufactured. PCDs contained detailed cost information for every product that UCC manufactured, including the materials and quantities used in production. PCDs were produced monthly and annually, not for particular projects. The PCD for any given year consisted of approximately 3,000 pages.

MASs are inventory control reports containing a transaction summary for every material UCC manufactured or purchased, each of which was assigned a unique product code. Material production and consumption information was contained in both PCDs and MASs. However, PCDs were organized by manufactured product, whereas MASs were organized in numerical order by product code and listed all transactions for each product code by location.

2. CMAI Data for Ethylene Byproducts

Additional products made during the manufacturing process of the primary product were listed as byproducts on PCDs. UCC's

material accounting system treated the cost of byproducts as a reduction in the cost of the primary product.

Taft's hydrocarbons unit made several ethylene byproducts such as propylene, butadiene, dripolene, hydrogen, methane, and acetylene. Because these byproducts are made from the same starting materials as ethylene, it is difficult to separately allocate the supply costs attributable to each byproduct. For this reason, Ms. Hinojosa used historical 1994 and 1995 market values of ethylene byproducts as a proxy for their supply costs. These market values were provided by Chemical Market Associates, Inc. (CMAI), a leading petrochemical industry consulting and research firm.

Ms. Hinojosa used the byproduct values provided by CMAI to calculate the supply costs incurred in conducting the UOP GA-155 project on the Olefins-1 unit's C_3 column, which produced ethylene byproducts (such as propylene, butadiene, and dripolene) as opposed to ethylene, which had already been separated off in the C_2 column. In addition, Ms. Hinojosa deducted these byproduct values from Taft's total ethylene production cost, from which she calculated the supply costs for the Amoco anticoking and sodium borohydride projects. This treatment of byproducts avoided double-counting the supply costs incurred in conducting the claim projects.

3. Wage Information

UCC's accounting system tracked budgeted and actual period costs (fixed costs, costs that do not fluctuate with production) such as labor. UCC's accounting system generated accounting records known as account levels. Account levels are the best source of information for calculating wage costs. However, account levels were not available for the credit years. Therefore, for the claim projects conducted in Taft's hydrocarbons unit (the Amoco anticoking, spuds, UOP GA-155, and sodium borohydride projects), Ms. Hinojosa used the annual salaries found on Forms W-2, Wage and Tax Statement, for specific employees involved in the projects. For the UCAT-J project, Ms. Hinojosa used Star budget reports that provided the total wage cost during the claim years and allocated that cost using the percentage of PE pounds produced during the UCAT-J runs relative to Star's total PE production during the same period. Wages represented 1 percent of the total cost of all of the claim projects.

4. R&D Budgets

Ms. Hinojosa did not refer to budgets prepared by UCC during the credit years. UCC's hydrocarbons R&D department did not prepare formal budget proposals specific to individual projects, but it did prepare an overall R&D budget that referenced various projects that would occur during the year. The R&D budget

generally included wages, laboratory materials, travel, and extraordinary expenses. Plant materials were generally included in the plant budget, not the R&D budget. Accordingly, R&D did not account for feedstock or fuel when estimating how much of its budget would be allocated to projects conducted on commercial plants.

B. Costs of the Amoco Anticoking Project

1. Supplies

Ms. Hinojosa calculated the supply costs of the Amoco anticoking, spuds, and sodium borohydride projects on the basis of the total ethylene manufacturing cost of Taft's hydrocarbons unit in 1994 and 1995. Ms. Hinojosa identified the materials as material quantities used to manufacture ethylene at Taft from the relevant PCDs and MASs.

In calculating Taft's total ethylene production cost for 1994 and 1995, Ms. Hinojosa included only major components of supplies that were supported by available accounting records. Specifically, Ms. Hinojosa included certain materials purchased from third-party vendors and certain internally produced materials.

Ms. Hinojosa did not include any general plant utilities such as electricity, treated water, nitrogen, or compressed air in her calculations. However, Ms. Hinojosa did include the cost of the fuel gases (such as natural gas, methane, and hydrogen)

used to fire Taft's ethylene furnaces and the refrigeration used in the cold section of the ethylene production process. Ms. Hinojosa included these costs because it was necessary to rapidly reduce the temperature of the raw material stream at various points in the production process in order to maximize the production of ethylene. To the extent that these costs are considered utilities, Ms. Hinojosa considered them to be extraordinary costs, different from general plant utilities, because of the energy-intensive nature of the ethylene production process relative to UCC's other manufacturing units.

Ms. Hinojosa used the relevant pages from the 1994 and 1995 MASs to calculate UCC's actual per-unit cost for both materials purchased from third parties and internally produced materials. She multiplied these actual unit costs by the quantities used (as shown on the relevant PCDs and MASs) to derive the total cost of materials used in manufacturing ethylene at Taft.

UCC was a net ethylene purchaser as it did not produce sufficient amounts of ethylene to meet the raw material requirements of its downstream products. UCC made up the difference by purchasing ethylene from third-party suppliers. Accordingly, to determine UCC's ethylene cost, Ms. Hinojosa calculated a pooled ethylene price based on the weighted average of Taft's ethylene production cost (derived from PCDs and MASs)

and the price that UCC paid for ethylene supplied by third parties as reported in a hydrocarbons business report.

After calculating the total cost of materials used to manufacture ethylene, Ms. Hinojosa subtracted the cost of ethylene coproducts and byproducts to isolate the supply costs attributable specifically to ethylene. Ms. Hinojosa obtained the quantities of coproducts and byproducts from the relevant PCDs and MASs. As discussed above, the unit costs of the deducted byproducts were based on historical 1994 and 1995 market value data provided by CMAI.

Using this methodology, Ms. Hinojosa determined that Taft's total ethylene production cost was $96,947,718 in 1994 and $97,479,242 in 1995. Ms. Hinojosa calculated the supply costs for the Amoco anticoking, spuds, and sodium borohydride projects by allocating Taft's total ethylene production costs in 1994 and 1995 according to (1) the duration of the projects and (2) the percentage of the production capacity of Taft's hydrocarbons unit employed in the projects. Ms. Hinojosa did not add the cost of any extraordinary supplies that were purchased specifically for the claim projects. If UCC increased the supplies it used during the projects or altered its production rate while conducting the projects, these facts are not reflected in Ms. Hinojosa's calculations.

For the Amoco anticoking project, Ms. Hinojosa calculated the supply costs by multiplying Taft's average daily ethylene production cost ($265,610 in 1994 and $267,066 in 1995) by (1) the project duration (30 days in 1994, 173 days in 1995) and (2) the fraction of the production capacity of Taft's hydrocarbons unit employed in the project (one-seventeenth). Petitioner claims that the Amoco anticoking project lasted from the start of the first pretreatment on November 29, 1994, until a furnace cold turnaround in mid-August of 1995. Petitioner included the materials cost for producing ethylene in all six (four treated and two untreated) cracking sets.

To avoid double-counting of supplies used in conducting both the Amoco anticoking project and the sodium borohydride project, Ms. Hinojosa eliminated the supplies used during the 1-week sodium borohydride project from her supply cost calculation for the Amoco anticoking project.

Ms. Hinojosa calculated UCC's supply QREs for the Amoco anticoking project as $468,723.86 and $2,717,793.54 for 1994 and 1995, respectively.

2. Wages

For the projects conducted at Taft's hydrocarbons unit, Ms. Hinojosa determined wage rates for the employees who were primarily involved in the projects and multiplied those rates by the number of hours that the employees estimated they had worked

on the project. For the Amoco anticoking project, Ms. Hinojosa determined that Mr. Hyde, Mr. Tregre, and Mr. Gorenflo spent 35, 5, and 2 hours working on the project in 1994 and that Mr. Hyde spent 10 hours working on the project in 1995. Mr. Hyde's wage rate was $21 per hour, Mr. Tregre's wage rate was $20 per hour, and Mr. Gorenflo's wage rate was $19 per hour. Ms. Hinojosa derived the wage rates from the employees' annual salaries, decreased by estimated overtime and profit-sharing.

Ms. Hinojosa calculated petitioner's wage QREs for the Amoco anticoking project as $873 and $210 for 1994 and 1995, respectively.

C. Costs of the Spuds Project

Petitioner's claimed amount for supplies used during the spuds project was also based on UCC's total manufacturing costs for 1995, which were then prorated between Olefins-1 and Olefins-2 according to production capacity. Petitioner claims as QREs one-seventeenth of its production costs for the 89 days after UCC changed the spuds on furnace 3. Ms. Hinojosa calculated as QREs $1,188,445.55 for supplies attributable to the spuds project in 1995.

Ms. Hinojosa calculated the wage costs for the spuds project using the same methodology she used to calculate wage costs for the Amoco anticoking project, discussed above. Ms. Hinojosa determined that Mr. Tregre spent 70 hours in 1994 and 10 hours in

1995 on the project and that Mr. Gorenflo spent 10 hours in 1995 on the project. Ms. Hinojosa calculated as QREs $1,400 and $390 for wages attributable to the spuds project in 1994 and 1995, respectively.

However, petitioner no longer claims any QREs attributable to the spuds project.

D. Costs of the UOP GA-155 Project

1. Supplies

UCC conducted the UOP GA-155 project in the Olefins-1 unit's C_3 column, downstream of the C_2 column where ethylene was separated from the process flow. The C_3 column processed the ethylene byproducts (propylene, butadiene, and dripolene). The supply costs for the UOP GA-155 project are based on the cost of the materials running through the C_3 column during the test. Ms. Hinojosa calculated this cost by multiplying the CMAI material values for each of the byproducts by their respective feed rates into the C_3 column and the project duration. The claimed supply costs include costs for plant feed, energy, and other costs of manufacturing products in Olefins-1 for 179 days (from September 22, 1994, through March 21, 1995). Ms. Hinojosa also included the costs of the UOP GA-155 additive, which were $14,077 and $24,534 for 1994 and 1995, respectively.

Ms. Hinojosa calculated UCC's supply QREs for the UOP GA-155 project as $20,707,920 and $23,117,359.20 for 1994 and 1995, respectively.

2. Wages

Ms. Hinojosa calculated the wage costs for the UOP GA-155 project using the same methodology she used to calculate the wage costs for the Amoco anticoking project, discussed above. Ms. Hinojosa determined that Mr. Brandon spent 220 hours working on the UOP GA-155 project during each of the credit years. Mr. Brandon's wage rate was $21 per hour. Ms. Hinojosa calculated UCC's wage QREs for the UOP GA-155 as $4,620 for each of the credit years.

E. Costs of the Sodium Borohydride Project

Ms. Hinojosa calculated the claimed supply costs of the sodium borohydride project using the same methodology she used to calculate the claimed costs for the Amoco anticoking project, discussed above.

Ms. Hinojosa calculated the supply costs for the sodium borohydride project by multiplying Taft's average daily ethylene production cost in 1995 ($267,066) by (1) the project duration (7 days) and (2) the percentage of the production capacity of Taft's hydrocarbons unit employed in the project (approximately 67 percent). Accordingly, Ms. Hinojosa calculated UCC's supply QREs for the sodium borohydride project as 1,248,300.86 for 1995. The

production cost included $55,583 for the sodium borohydride additive.

Ms. Hinojosa calculated UCC's wage QREs as $4,620 for the sodium borohydride project using the methodology she used to calculate wage costs for the Amoco anticoking project, discussed above. Ms. Hinojosa determined that Mr. Brandon spent 220 hours working on the sodium borohydride test in 1995.

F. Costs of the UCAT-J Project

1. Supplies

For the UCAT-J project, Ms. Hinojosa used the PCDs for the PE base resins made in the UCAT-J experimental runs to identify the materials and material quantities used in the runs. For UCAT-J runs 3 and 15, Ms. Hinojosa did not have a PCD for the specific product that was made (DJM-1732H), and she accordingly used a PCD for a similar product (DJM-1734H). Ms. Hinojosa did not include any costs classified on the PCDs as utilities or the costs of additives incorporated into base resins during postreaction pelleting. Ms. Hinojosa then used 1994 and 1995 MASs to calculate the actual per-unit cost of purchased materials used in the UCAT-J project. Because UCC used both purchased and internally produced ethylene to manufacture PE, Ms. Hinojosa used a pooled ethylene price.

Ms. Hinojosa used the 1994 and 1995 MASs to calculate the unit costs of the UCAT-J reduction agents (DEAC and TnHAl) and

hydrogen mix used in UCAT-J runs. For the internally produced UCAT-J precursor, Ms. Hinojosa used 80 percent of the standard cost shown on the PCDs.

Petitioner claims as QREs for supplies $2,006,700 and $4,670,900 for 1994 and 1995, respectively, for the UCAT-J project.

2. Wages

The UNIPOL reactors in Star's LP-3 unit operated continuously during the UCAT-J credit year experimental runs, with production staff supporting the reactors 24 hours per day on 12-hour rotating shifts. According to Ms. Hinojosa, the amount of time spent by plant operators and other support staff did not vary significantly for experimental UCAT-J runs as compared to normal production runs.

Ms. Hinojosa calculated the wage QREs attributable to the UCAT-J project by allocating Star's total wages in 1994 ($8.92 million) and 1995 ($9.72 million) according to the percentage of Star's total PE production made during the UCAT-J experimental runs in 1994 (2.1 percent) and 1995 (4.18 percent), adjusted for reactor downtime.[17]

[17]Ms. Hinojosa reduced wages for downtime in response to a comment from Mr. Allen, one of respondent's expert witnesses. In response to another comment from Mr. Allen, Ms. Hinojosa also calculated wages using an allocation based on the duration of the runs instead of production. Ms. Hinojosa believes that the impact of this change was insignificant and therefore did not

(continued...)

Petitioner claims as QREs for wages $167,839 and $351,040 for 1994 and 1995, respectively, for the UCAT-J project.

IV. Base Period Projects

The second special trial session focused on petitioner's revised base period computations (base period trial).[18] Petitioner arrived at a revised base amount by identifying additional activities that it believes constitute qualified research within the meaning of section 41(d) (identified runs) and calculating the cost of those identified runs.

A. Scope of the Trial

On September 15, 2006, petitioner filed a motion for partial summary judgment seeking to: (1) Limit the scope of the evidence at the base period trial to QREs incurred by UCC, as opposed to petitioner's entire consolidated group; and (2) shift the burden of proof on the base period issues to respondent.

By an order dated January 17, 2007, the Court granted petitioner's motion in part and denied it in part, informing the parties in pertinent part that: (1) Petitioner would bear the burden of production with respect to its revised base period computations; (2) for purposes of conforming the base period computations to the methodology petitioner employed to compute

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[17](...continued)
alter her methodology.

[18]The "base period" includes the years beginning after Dec. 31, 1983, and before Jan. 1, 1989. See sec. 41(c)(3)(A).

the claimed credits, only evidence of the revised base period computations for the legal entity for which additional credits are claimed would be necessary; (3) in the above-described legal entity computations, it would be necessary to produce evidence to revise the base amount for businesses acquired by the legal entity after December 31, 1983, and not disposed of before January 1, 1994; and (4) if petitioner could show that any dispositions that occurred before 1994 played no role in the computation of QREs of the legal entities in the return as filed, then petitioner would not have to account for dispositions of those trades or businesses in conforming the base period computations to the methodology used to claim additional credits for the years at issue.

Because petitioner's claimed credits all relate to alleged QREs incurred by UCC as a single legal entity, the scope of the base period portion of the trial was limited to research that UCC conducted, including research conducted by any businesses that UCC acquired after December 31, 1983, and did not dispose of before January 1, 1994.

1. Organization of UCC's Manufacturing Operations During the Base Period

During the base period UCC operated its C&P business segment as well as various other business segments, including consumer products, carbon products, and industrial gases. As a result of a divestiture policy that UCC pursued in the late 1980s and early

1990s, the C&P business segment was the only UCC business segment remaining during the credit years. Accordingly, when petitioner revised UCC's base amount for QREs incurred at UCC's manufacturing plants during the base period, petitioner included only QREs that were incurred within UCC's C&P business segment.

During the base period UCC's C&P business consisted of four divisions that corresponded to product groupings: (1) The industrial chemicals division; (2) the polyolefins division; (3) the solvents and coatings materials division; and (4) the specialty chemicals division.

The industrial chemicals division encompassed 19 separate manufacturing units that collectively produced ethylene and other olefins, ethylene oxide/ethylene glycol, various ethylene oxide derivatives, and other products at Taft; Seadrift; UCC's Texas City, Texas plant (Texas City); UCC's Institute, West Virginia, plant (Institute); and UCC's Washougal, Washington, plant (Washougal).

The polyolefins division encompassed six manufacturing units that collectively manufactured commodity and specialty PE products at Seadrift and Star as well as a wire and cable compounding plant in Bound Brook. UNIPOL was a part of the polyolefins division during the base period and was the largest consumer of R&D funding within the division.

The solvents and coatings materials division encompassed 21 manufacturing units that collectively manufactured glycol ethers, acrylates, and various other solvents and coatings at UCC's Taft, Seadrift, Texas City, Institute, and South Charleston plants, as well as latex products at several small production facilities across the country.

The specialty chemicals division encompassed 13 manufacturing units that collectively manufactured a variety of low-volume, high-performance specialty chemicals, including acrolein derivatives, alkyl alkanolamines, Cellosize, and Polyox at Taft, Institute, and South Charleston.

2. Acquisitions and Dispositions Between the Claim Years and the Base Period[19]

a. Acquisitions

On November 16, 1990, UCC acquired particular assets of Rohm & Haas Co. (Rohm & Haas). The acquired assets included chemical formulas and other intellectual property associated with Rohm & Haas's worldwide surfactant and alkylphenol business under the trade name Triton (Triton assets). Surfactants are a family of organo-silicone molecules, including detergents and hard-surface cleansers. Following the sale of the Triton assets, all associated technical data and intellectual property were transferred to UCC.

[19]Acquisitions and dispositions that do not affect petitioner's revised research credit computations are omitted.

During the base period the Triton business represented a mature technology. Rohm and Haas had not performed any work to improve or add products to its portfolio in many years. During the base period and until the sale of the Triton assets to UCC, it was Rohm & Haas's practice to manage the Triton business as a "cash cow", harvesting substantial amounts of cash from the business while investing only limited resources for research and growth.

Rohm & Haas treated its sale of the Triton assets and its obligations under various agreements made in connection with the sale as a disposition of a major portion of a trade or business for purposes of the research credit computation. Likewise, UCC treated its purchase of the Triton assets and its obligations under the various agreements as an acquisition of a major portion of a trade or business for purposes of the research credit computation.

In 1990 UCC acquired the Norkool business from Quantum Chemical Corp. The Norkool products included industrial coolants and antifreeze formulations, corrosion inhibitor packages, and cooling system cleaners. During the base period one person was assigned to provide R&D support for most of the Norkool business, although additional R&D support analyzed Norkool's fluids to

ensure that they were properly balanced. In addition, there were engineers available to provide assistance if necessary.[20]

In 1990 UCC acquired the worldwide Polyphobe thickeners business and assets from De Soto, Inc. The Polyphobe thickeners were used in the formulation of latex paints.[21]

b. Dispositions

UCC's original base period QREs reflected allowable adjustments under section 41(f)(3)(B) attributable to dispositions by UCC of the major portion of a trade or business or the major portion of a separate unit of a trade or business. During the credit years there were no dispositions by UCC of the major portion of a trade or business or the major portion of a separate unit of a trade or business for which petitioner must adjust its base period QREs or gross receipts under section 41(f)(3)(B) other than the dispositions reflected in the base period QREs and gross receipts reported on UCC's original returns.

UCC divested itself of its home and automotive, agricultural products, film packaging, engineering polymers and advanced composites, worldwide metals, and battery products businesses in 1986. UCC sold a 50-percent interest in its carbon products

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[20]None of petitioner's original base period QREs were attributable to the Norkool business.

[21] None of petitioner's original base period QREs were attributable to the Polyphobe thickeners business.

business in 1991. UCC spun off its industrial gases business in 1992. Before January 1, 1994, UCC divested itself of the following additional businesses: Primary alcohol ethoxylates, polycrystalline silicon, urethane polyether polyols and propylene glycol, silicones and urethane catalysts, coatings service, phenolic resins, and phenoxy resins.

3. UCC/Shell Polypropylene Business

a. The Cooperative Undertaking

On December 22, 1983, UCC and Shell formed a tax partnership called the Cooperative Undertaking, pursuant to a legal agreement entitled the "Cooperative Undertaking Agreement" (CUA). UCC and Shell each contributed goods and services in return for a 50-percent interest in the Cooperative Undertaking. According to the CUA, the purpose of the Cooperative Undertaking was to develop and adapt UCC's UNIPOL technology to incorporate Shell's catalyst technology and create a combined commercial process for the manufacture of polypropylene (combined commercial process). The Cooperative Undertaking planned to license the combined commercial process to third parties. Shell was also interested in producing polypropylene using the combined commercial process.

The CUA envisioned a three-phase process.[22] In phase I, UCC and Shell would develop acceptable pilot plant operating

[22] As discussed below, some of the activities envisioned by the CUA were not actually performed by the Cooperative Undertaking.

conditions and produce acceptable polypropylene resin. In Phase II, UCC would construct a demonstration plant at Seadrift and scale up manufacture of polypropylene resin from the pilot plant to the demonstration plant. In addition, Shell would develop preliminary commercial markets for the sale of cooperatively made polypropylene resin using the combined commercial process. In phase III, certain limited licenses between UCC and Shell would become effective; UCC and Shell would operate the demonstration plant to produce cooperative polypropylene resin using the combined commercial process; UCC would solicit, grant, and administer third-party licenses with Shell's assistance; and UCC and Shell would continue to cooperate to improve the combined commercial process. On January 29, 1987, phase II ended and phase III began.

Under the CUA, UCC and Shell each paid their own costs for R&D covered by the CUA and retained sole intellectual property rights for information they developed separately during phases I and II. However, UCC and Shell would share all net licensing revenue equally during phase III. UCC and Shell would jointly own any intellectual property jointly developed during any phase.

UCC and Shell agreed that the Cooperative Undertaking was a partnership solely for tax purposes. The Cooperative Undertaking accordingly filed Federal and State partnership tax returns with UCC serving as the tax matters partner. However, the CUA

expressly excluded from the CUA tax partnership: (1) All research activities conducted individually by UCC and Shell during phases I and II; and (2) all activities conducted by Seadrift Polypropylene Co. (SPC). As discussed below, SPC was to conduct all manufacturing activities using the combined commercial process and the Cooperative Undertaking would not engage in any manufacturing activities or plant-based experiments.

b. SPC

On March 21, 1984, UCC and Shell formed SPC as a partnership under the laws of the State of Texas. UCC and Shell each contributed goods and services in return for a 50-percent interest in SPC. SPC filed Federal and State partnership tax returns, with Shell serving as the tax matters partner and providing accounting services.

The purpose of SPC was to construct and operate a demonstration manufacturing plant, the P-1 unit, which would be used to commercialize the combined commercial process developed by the Cooperative Undertaking, demonstrate the combined commercial process to licensees and potential licensees, and produce polypropylene. Only SPC, not the Cooperative Undertaking, would conduct polypropylene manufacturing operations.

Also on March 21, 1984, SPC retained and designated UCC as an independent contractor to design and construct the P-1 unit. SPC leased existing plant facilities and land from UCC so that UCC could build the P-1 unit within the confines of Seadrift. Under the contract signed with SPC (the engineering and construction contract), SPC paid UCC a fixed price for the design and construction work on the P-1 unit. Under the engineering and construction contract, UCC would own any intellectual property that it developed in the course of designing and constructing the plant under the contract. Petitioner did not include any activities that occurred under the engineering and construction contract during the base period in either its original or revised base period calculations.

Pursuant to another agreement between UCC and SPC (the operating agreement) dated March 21, 1984, SPC retained UCC as an independent contractor to serve as the operator of the P-1 unit. In this capacity, UCC initially incurred the costs of SPC’s polypropylene manufacturing operations, including variable costs such as raw materials and period costs such as plant labor. UCC purchased polypropylene and catalysts directly from Shell. UCC submitted monthly invoices for these costs to SPC, and, pursuant to the operating agreement, SPC reimbursed UCC for these costs. The operating agreement provided that any intellectual property discovered or developed by UCC in the course of performing its

duties would be governed by the CUA, not the operating agreement or any other SPC agreement.

SPC did not maintain a separate set of books and records. However, in its capacity as an independent contractor UCC maintained SPC's accounting records and identified SPC as a separate business.

In the mid-1990s UCC sued Shell and various other entities, claiming, inter alia, that Shell had violated its fiduciary duty with respect to the joint venture. The litigation settled, and on January 18, 1996, UCC acquired Shell's polypropylene business assets, including Shell's interest in SPC, as part of the settlement.

c. Petitioner's Base Amount Recalculation

Petitioner did not include the cost of any research conducted at P-1 during the base period in its base amount because petitioner believes that SPC, not UCC, incurred the costs of that research. However, petitioner identified 138 runs that occurred at P-1 during the base period that it would treat as qualified research in the event that the Court finds that UCC, not SPC, incurred the costs of these runs (polypropylene runs).[23] Petitioner determined that the 138 runs that occurred at P-1 during the base period cost $29,508,628.41.

[23]The criteria used to identify the research that petitioner believes constitutes qualified research within the meaning of sec. 41(d) are discussed below.

B. Base Period Projects

1. UCC's Focus on R&D During the Base Period and Credit Years

UCC viewed manufacturing process improvements as important during both the base period and the credit years. UCC's manufacturing process was continuously evolving throughout these years. In particular, in the early 1990s William Joyce, the president of UCC's polyolefins division, implemented a new process improvement program designed to lower costs. Mr. Joyce implemented this program as part of a program to increase UCC's licensing business.

2. The Role of R&D and Engineering at UCC's Manufacturing Plants

During the base period, R&D provided plant support to all four C&P divisions. R&D supported the operation and safety of the plants and monitored the quality of the products. UCC's engineering and manufacturing departments also helped to develop UCC's manufacturing process. Plant-based experiments were typically carried out through multifunctional teams.

There was no formal rule during the base period regarding how many successful runs of a new product must be conducted before the product is deemed to be commercial. However, in the polyolefins division UCC generally preferred to conduct at least three runs on a new product before deeming it commercial.

3. Petitioner's Identification of Plant-Based Qualified Research Activities Conducted During the Base Period

a. Dr. Wadia's Assignment

Parvez H. Wadia, one of petitioner's expert witnesses, was qualified in the base period trial as an expert in conducting R&D related to the manufacturing of chemicals and plastics.[24] Dr. Wadia's task was to identify all activities that UCC conducted at its domestic C&P manufacturing facilities during the base period that Dr. Wadia believed constituted "qualified research" as defined by petitioner's counsel. The criteria that Dr. Wadia used to select the identified runs are referred to as the "qualified research criteria", and the activities that Dr. Wadia believes satisfy the qualified research criteria are referred to as the "identified runs".[25] Another of petitioner's expert witnesses, Sheri L. Toivonen, calculated the costs of the identified runs.[26]

Dr. Wadia was not familiar with the claim projects before beginning his task. At petitioner's request Dr. Wadia later compared the identified runs with the spuds project. However,

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[24]Dr. Wadia's qualifications are set out in the Opinion section, below.

[25]We make no finding at this time whether the identified runs constituted qualified research within the meaning of sec. 41(d).

[26]Ms. Toivonen's qualifications are set out in the Opinion section, below.

Dr. Wadia was not asked to opine whether the claim projects satisfy the qualified research criteria or to identify activities similar to the claim projects that occurred during the base period.

Dr. Wadia was assisted by five other professionals from Mid-Atlantic Commercial Research, a subsidiary of the Mid-Atlantic Technology, Research & Innovation Center (MATRIC) (collectively, MATRIC team[27]). MATRIC's largest client is the United States Government. The MATRIC team had more than 224 years of experience in the chemicals and plastics industry and 171 years of experience with UCC. None of the MATRIC team members testified as fact witnesses during the trial.

The qualified research criteria closely tracked the definition of qualified research under section 41(d) and section 1.41-4, Income Tax Regs.[28] The criteria required Dr. Wadia to consider five key questions: (1) Does the research activity seek to eliminate an uncertainty concerning the development or improvement of a business component, which can be either a product or a process? (2) Does the research activity seek technological information? (3) Does substantially all of the

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[27]Although the company that petitioner retained was a subsidiary of MATRIC, the parties generally refer to the team as being from MATRIC. We adopt that designation for convenience.

[28]As we explain infra note 42, respondent concedes that petitioner may rely on sec. 1.41-4, Income Tax Regs., even though it is effective for years ending on or after Dec. 31, 2003.

research activity involve elements of a process of experimentation? (4) Does the research activity relate to a qualified purpose? (5) Is the activity an "excluded activity"? Dr. Wadia was provided with a list of excluded activities that tracked section 41(d)(4). To be consistent with petitioner's selection of the claim projects, petitioner asked Dr. Wadia to identify only plant-based experiments that occurred at UCC's domestic manufacturing facilities.

b. Dr. Wadia's Methodology

Dr. Wadia and his team spent approximately 5,650 hours selecting the identified runs. This time was spent reviewing over 120,000 pages of technical documents, conducting electronic searches, interviewing 157 current and former Dow and UCC employees, and visiting 42 of Dow's unit libraries and 69 satellite libraries. The technical documents that the MATRIC team reviewed included, but were not limited to, R&D project reports and project memoranda, definition of technology reports, technology manager's reports, UNIPOL strategic run plans and tactical run plans, and latex process and commercial product information. Dr. Wadia reviewed a few FOCRs, but most of the FOCRs that had been produced during the base period were no longer available. Dr. Wadia's project identification investigation was highly interactive and often complex, nonlinear, and iterative.

For each of the identified runs, Dr. Wadia defined the activity by providing: (1) A run description; (2) the manufacturing plant locations and specific manufacturing units; (3) the product(s) made during the activities and their production volumes; (4) the raw materials and catalysts used to make the product(s); (5) the start and end dates of the activities; (6) any other relevant scientific information; and (7) the documents related to the identified runs.

Dr. Wadia used a somewhat modified process with respect to UCC's crystal products business based at Washougal, which UCC sold to an unrelated third party in 1999. Dr. Wadia used a "top-down" approach to estimate how much UCC spent on plant-based experimentation for this business. To make this estimation, Dr. Wadia assumed that: (1) Annual sales for the business ranged from $9 to $10 million per year; (2) manufacturing cost as a percent of sales was 60 percent; and (3) about 5 to 10 percent of the crystal growth stations for manufacturing products were dedicated to experimental work. The plant manager for the Washougal crystal products plant confirmed that he believed that these were reasonable estimates.

c. Dr. Wadia's Conclusions

Dr. Wadia identified a total of 793 separate plant-based activities that he believes satisfy the qualified research

criteria.[29] Dr. Wadia originally identified 764 runs in his opening expert report dated August 3, 2007. After receiving and reviewing additional information, Dr. Wadia identified 29 additional runs that he listed in his supplemental expert report dated October 26, 2007. Dr. Wadia also revised the duration and production of runs 408, 574, and 777 at that time.

The MATRIC team considered thousands of projects. Dr. Wadia rejected some projects at the outset because they occurred outside the base period, were not conducted at a manufacturing facility, or otherwise clearly did not satisfy the qualified research criteria. The MATRIC team then discussed the remaining potential projects, and Dr. Wadia decided whether they satisfied the qualified research criteria. The MATRIC team did not retain a list of potential projects that were discussed but not included on the list of identified runs. Dr. Wadia was satisfied that the MATRIC team had sufficiently analyzed each project and did not feel that such a list was necessary.

Dr. Wadia listed the identified runs as runs 1 through 806 on the exhibits to his initial and supplemental expert reports.[30] Dr. Wadia later produced a table of identified runs that includes

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[29]These runs are listed as runs 1 through 806. Dr. Wadia did not identify any runs as run 121, 278, 524, 525, 526, 527, 679, 687, 688, 689, 690, 691, or 775.

[30] As discussed above, Dr. Wadia has not identified any runs as Run 121, 278, 524, 525, 526, 527, 679, 687, 688, 689, 690, 691, or 775.

comments on the runs. In his expert report Dr. Wadia discusses the specific manufacturing units that conducted the runs and provides additional narrative information regarding many of the runs.

d. Petitioner's Concessions

As a result of fact witness testimony at trial, petitioner, with the assistance of Dr. Wadia, conceded that 14 additional plant-based research activities conducted during the base period satisfy the qualified research criteria (runs 807 through 820). Ms. Toivonen summarized each of the conceded activities, provided references to pertinent testimony and documents, and provided calculations of the cost of the research activities on the basis of the referenced information and relevant accounting records. The pertinent conceded runs are discussed below.[31]

i. Nalco Inhibitor Antifouling Test (Run 816)

Dr. Wadia did not include the Nalco inhibitor antifouling test among the first 793 identified runs, but petitioner later conceded that this test satisfies the criteria for qualified research and added this test as run 816.

[31]As discussed in the Opinion section, respondent argues that the fact that Dr. Wadia did not initially include runs 807 through 820 illustrates a flaw in his methodology. While we state no opinion on respondent's argument at this time, we provide pertinent facts regarding the runs that respondent addresses in his argument.

During the base period UCC worked with Nalco Chemical (Nalco) to develop a type of antioxidant or fouling inhibitor to inject into the C_2 column, which would then enter the C_3 column and prevent fouling in that column. If successful, this would minimize the number of times the reboiler had to be cleaned and extend the number of months the reboiler could operate without being shut down.

Nalco approached UCC with a fouling inhibitor for UCC to test. UCC most likely would have prepared an FOCR for the installation of the pumping facilities to inject the inhibitor and for the addition of a new chemical into the plant.

UCC tested the Nalco inhibitor for 5 to 6 months. UCC personnel monitored the steam pressure on the C_3 column reboiler and checked the reboiler for fouling during the test.

The inhibitor extended the length of time the reboiler ran without being cleaned and the steam pressure was reduced. As a result of these findings, UCC determined that the Nalco inhibitor worked as it was intended to work and did not perform additional testing.

Ms. Toivonen determined that the Nalco inhibitor antifouling test cost $7,192,670.85.

ii. Wastewater Activity (Run 809)

Another activity that Dr. Wadia did not include as an identified run in his original or supplemental report was a plant

test performed at Taft's wastewater treatment facility. UCC received a tank truck of wastewater from another plant and processed the tank through the wastewater treatment facility at Taft.

A technology highlights memorandum describes the activity as a "plant test" that would be run in mid-November of 1985. The activity would involve dumping half of the tank into the wastewater facility at a rate of 2 gallons per minute and monitoring for odor. UCC would rapidly dump the remaining 2,900 gallons in two stages. In the first stage UCC would dump 1,450 gallons into the acrylics sump. If that caused odor problems, UCC would dump the remaining 1,450 gallons into a different sump. If the dumping of the first 1,450 gallons did not cause odor problems, UCC would also dump the remaining 1,450 gallons into the acrylics sump.

Ms. Toivonen calculated the QREs associated with this activity to be $8,441.65.

iii. Rohm & Haas Runs (Runs 813 and 814)

Dr. Wadia included two runs associated with the Triton assets in his expert witness report as identified runs. Ms. Toivonen calculated the cost of these two runs as $1,489.06 and $39,630.61, respectively. Petitioner later conceded that two additional runs (runs 813 and 814) associated with the Triton asset should have been included in its base amount calculation.

In her second supplemental expert witness report Ms. Toivonen calculated the costs of these runs as $21,826.32 and $345,683.94, respectively. This concession doubled the number of identified runs associated with the Triton assets and increased the costs of the identified runs associated with the Triton assets nearly tenfold.

e. Activities That Were Not Identified Base Period Activities

Respondent argues that Dr. Wadia should have included the following additional activities on the list of identified runs.

i. NOx

Dr. Wadia did not include as identified runs any activities related to NOx. "NOx" refers to various compounds of nitrogen and oxygen that can be contained in catalytically cracked refinery gases that are sometimes fed to ethylene units. NOx can accumulate in the cryogenic sections of commercial ethylene units. These cryogenic sections, called "cold boxes", separate very low boiling point materials in the cracked furnace gas as part of the ethylene recovery process. Nitric oxide (NO), a compound of NOx, has very low boiling and freezing points. Therefore, nearly all of the NO in the ethylene unit cracked gas stream enters the cold box. NO may be oxidized to NO_2 in the cold box by the presence of oxygen, and NO_2 can react with additional NO to form N_2O_3.

Some NOx compounds (NO_2 and N_2O_3 in particular) freeze and boil at significantly higher temperatures than NO. Therefore, NOx compounds can freeze in the cold box and accumulate. The accumulation of NOx compounds in the cold box can present a significant safety hazard. Some NOx compounds are highly reactive and can combine with other materials, in particular butadiene, in the cold box to form NOx gums. NOx compounds also react with ammonia to form ammonium nitrate and nitrite (NOx salts). While stable at the very low cold box temperatures, NOx gums and NOx salts can become unstable and explosive when the cold box is warmed. NOx gums may explode at temperatures well below ambient, while NOx salts require warmer temperatures to explode. Even small amounts of explosive gums can be a serious safety hazard.

UCC was aware of the potential safety hazards of NOx accumulation in cold boxes long before the base period. UCC had not had an NOx-related explosion before the base period, but it had been aware of NOx-related explosions in other cryogenic gas processing units in the chemical industry.

By 1982 it was generally known that thawing a cold box would remove NOx that had accumulated in the cold box. A controlled thaw involves shutting off the cracked furnace gas feed, gradually warming the cold box to ambient temperature, and injecting purge gas through the piping to flush out the NOx

compounds. It was also generally known how fast to warm the cold box and to what temperature to warm the cold box to minimize the risk of explosion. Furthermore, it was generally known that after a thaw a cold methanol wash could be used to remove NOx gums from the cold box equipment and at what temperature the cold methanol wash should be used.

During the base period it was industry practice to thaw cold boxes periodically. UCC thawed its cold boxes approximately once per year during the 1980s but had not used a methanol wash until July 1985. Before the base period UCC had never quantified the amount of accumulated NOx or the rate of NOx accumulation in any of its olefins units' cold boxes.

By late November 1984 operations personnel at Texas City had determined that they did not have enough information to define a safe run length for the cold box. During several earlier thaws UCC had checked the effluent from the Texas City cold box for NOx. UCC found NOx in the effluent on every occasion but never quantified the amount or determined the form or type of NOx compounds present in the Texas City cold box. UCC used a chemical method called the Griess-Saltzman method to detect the presence of NOx. UCC also used Draeger tubes (another analytical technique) to measure NOx concentrations in the cold box vent gas. UCC thought that the NOx that was accumulating might be NOx gums.

In December 1984 Luis Batiz, an engineer in Texas City's olefins unit, sent a letter to the hydrocarbons R&D technology manager expressing concern about the potential accumulation of NOx compounds in the Texas City cold box and requesting assistance in developing a standard philosophy and general procedure that could be implemented in Texas City to thaw the cold box. The Texas City olefins unit was particularly susceptible to NOx accumulation because it used refinery gas, which was known to contain NOx, as a raw material. At that point the Texas City cold box had been operating continuously for about 1 year without a thaw. UCC had no way to estimate how much NOx had accumulated because UCC had not previously quantified the accumulation of NOx.

Mr. Batiz's request was assigned to Dr. Henstock, a project scientist in UCC's hydrocarbons R&D group, in early 1985. Dr. Henstock was based at the technical center in South Charleston. Dr. Henstock researched the issue, reviewed the situation at Texas City, and concluded that the Texas City personnel did not have enough information to determine a safe run length or set their own operating guidelines. In February of 1985 Dr. Henstock informed his supervisors that while the hazards of NOx had been known for some time, the formation of NOx deposits and their removal was still not well understood. Dr. Henstock decided to conduct a controlled thaw as soon as was practical and measure

the amount of NOx that was liberated from the cold box to determine the rate at which it was accumulating. UCC intended to use this information to determine how frequently the cold box must be thawed.

In order to better analyze the amount of NOx that came out of the cold box, UCC's South Charleston technical center built a prototype of a photoionization analyzer. The photoionization analyzer gave readings every 2 to 3 minutes, recorded data automatically, and could be left unattended. UCC believed that this method for analyzing NOx was superior to the Griess-Saltzman method because the Griess-Saltzman method did not give readings frequently, was very time consuming, required skill to operate, and could not be operated unattended.

The first Texas City thaw began on February 19 and ended on February 24, 1985. This was UCC's first attempt to measure accumulated NOx. During the thaw an operator noticed a bright blue liquid leaking from a cold box valve, which was not expected. Dr. Henstock discussed this phenomenon with some of his colleagues in South Charleston, and they determined that the material was N_2O_3, which is not the form of NOx compound that Dr. Henstock had expected. Dr. Henstock then vented the material into the atmosphere while measuring the concentration and total flow rate in order to calculate the total amount. Dr. Henstock estimated that about 100 pounds of material had built up in the

cold box. Much of the NOx that had entered the system was from purchased refinery gas. Dr. Henstock did not determine whether NOx gums had formed. The rest of the cold box thaw was completed uneventfully and the cold box was returned to normal operation.

Dr. Henstock documented the February 1985 cold box thaw in a project report dated August 13, 1985. The project report summarized what occurred during the thaw and documented the results. Dr. Henstock was surprised and concerned about the amount of NOx that he found. Accordingly, Dr. Henstock recommended that the thaw be repeated in a few months to see how much NOx would accumulate in that time. Dr. Henstock also recommended that a methanol wash be performed to determine whether NOx gums had formed. UCC decided to have an external consultant perform laboratory work to understand the hazards of N_2O_3.

Recognizing the potential safety implications of the significant quantities of NOx found during the February 1985 thaw, UCC made the results of the thaw available to the olefins industry during the summer of 1985. The findings of the February 1985 thaw resulted in the formation of the Task Group on Nitrogen Oxides in Ethylene plans, which met four times from October 1985 to October 1986. The task group issued a report of its findings that identified potential problems regarding NOx and made suggestions on how to safely handle equipment likely to contain

NOx. Dr. Henstock also wrote a paper on NOx that was presented at an American Institute of Chemical Engineers (AIChE) meeting in the spring of 1986.

Following Dr. Henstock's recommendations, UCC performed another thaw of the Texas City cold box in July 1985, followed by a methanol wash. This was the first methanol wash that UCC had performed at any of its olefins facilities. UCC determined that less than 3 pounds of NOx had accumulated and that no NOx gums had formed.

Dr. Henstock wrote another project report to document the results of the July 1985 thaw. Because of the small amount of NOx accumulation found and the absence of NOx gums during this thaw, Dr. Henstock regarded the NOx issue as a manageable safety hazard at Texas City. Dr. Henstock postulated that much of the NOx passed through the cold box and flowed out in the fuel stream. Dr. Henstock recommended that a method should be developed for monitoring the NOx balance around the Texas City cold box, such as the installation of a permanent NOx analyzer. Dr. Henstock also recommended that future thaws at all locations be monitored closely to determine the amount of NOx accumulation. In the meantime, Dr. Henstock recommended that the Texas City cold box be thawed at least every 12 months. Dr. Henstock did not believe that methanol washes would be necessary at Texas City

in the future, but he recommended methanol washes at locations where NOx and butadiene could both enter the cold box.

In January 1986 UCC performed a thaw and methanol wash of the cold box and one of the two methane columns at Seadrift. Seadrift did not use refinery gas as a raw material. Therefore, UCC assumed that NOx accumulation at Seadrift was less likely than at Texas City. However, UCC had detected NOx at several points within the process, which indicated that there might be NOx present. UCC also believed that NOx and butadiene occasionally contacted one another, which could potentially cause the formation of NOx gums. UCC was concerned about an incident at Seadrift in which thaw gas flowing out of piping was found to be unexplainably warm during a cold box thaw in 1979. UCC had never quantified the accumulation of NOx or NOx gums or used a methanol wash at Seadrift before this thaw.

During the January 1986 thaw at Seadrift, UCC used the same general procedures it had used at Texas City. UCC did not find any NOx accumulation or NOx gums in the cold box. Dr. Henstock documented the results of the January 1986 thaw in a project report dated June 16, 1986. Dr. Henstock concluded that the warm thaw gas outlet pipe incident during the 1979 thaw was probably not related to NOx. Dr. Henstock also developed guidelines for future management of potential NOx hazards at Seadrift. Dr. Henstock determined that future Seadrift cold box thaws should be

closely monitored for NOx in the outflowing warmup gas but that methanol washes would not be required unless evidence of NOx gum formation developed.

UCC followed the plans recommended after the July 1985 thaw at Texas City and conducted another thaw at Texas City in January 1987. UCC improved the procedure it had previously used at Texas City by using a drain vaporizer when NOx levels were very low. UCC purged less than 1 pound of NOx during the January 1987 thaw.

Dr. Henstock documented the results of the January 1987 thaw in a project report dated March 11, 1987. Dr. Henstock concluded that the smaller accumulation was probably due to decreases in the level of NOx in the refinery gas. Dr. Henstock recommended careful monitoring of the refinery gas NOx concentrations once the permanent analyzer was installed later in 1987. Dr. Henstock also recommended that it was safe to increase the time between thaws to 24 months as long as the low NOx concentrations in the feed streams persisted, but he suggested reevaluating the time interval between thaws according to the results of the next thaw.

In March 1988 UCC measured NOx accumulation during a normal plant shut down and cold box thaw at Taft. Taft's Olefins-2 unit had run continuously for over 3 years at that point. UCC had never attempted to quantify the accumulation of NOx or NOx gums at Taft before this thaw. Taft did not use refinery gas as a raw material, but the design of the separations system at Taft

allowed some butadiene (known to form NOx gums) to enter the cold box. UCC analyzed the process streams feeding and leaving the cold box at Taft on three different occasions before the March 1988 thaw but found no measurable NOx.

During the March 1988 thaw UCC monitored the effluent for NOx and detected less than a pound of NOx. UCC did not detect any NOx gums or polymers on a visual inspection of the cold box and methane column feed separators. Dr. Henstock concluded that future monitoring of the Taft cold box by the hydrocarbon R&D group would not be necessary. However, Taft personnel would continue to check the cold box streams for NOx with Draeger tubes at any future shutdowns.

None of the thaws discussed above involved the changing of any variables before the NOx accumulation was measured. During each thaw UCC collected data for the purpose of determining how fast NOx was accumulating under normal conditions and how long the cold boxes could safely operate without being thawed. Dr. Henstock continued to study NOx into the 1990s and still considered NOx accumulation to be a safety issue at least as late as 2002.[32]

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[32]A serious NOx gum explosion occurred at the Shell Olefins plant in Berre, France, in 1990. A second industry task group was formed in response to this explosion. However, these events did not occur during the base period or the credit years, and accordingly we do not address them in detail here. A minor NOx-related explosion also occurred at Texas City in 1994. However,

(continued...)

Dr. Wadia did not include any NOx-related activities on the list of identified runs because the MATRIC team concluded that they did not involve a process of experimentation but merely constituted data collection and monitoring. Accordingly, Ms. Toivonen did not include the cost of any NOx-related activities in her expert witness report.

Roy T. Halle, one of respondent's expert witnesses, estimated that the cost of the ethylene that UCC produced at Texas City, Seadrift, and Taft during the periods leading up to the cold box thaws was about $443 million.[33]

ii. John Zink Co. Orders

UCC purchased equipment from the John Zink Co. during the base period. UCC conducted tests on equipment purchased from the John Zink Co. during the base period that Dr. Wadia did not include on his table of identified runs. These tests generally consisted of testing the products to see whether they functioned properly.

iii. Star Pelleting

In 1986 UCC installed one of the industry's largest and most effective pelleting lines at Star. UCC tested the new equipment

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[32](...continued)
none of the claim projects relate to this explosion. Accordingly, we need not discuss the event further.

[33]Mr. Halle's qualifications are set out in the Opinion section, below.

to validate that everything functioned as was expected. However, UCC did not take any steps to further develop the new pelleting line. UCC did not have any significant difficulties with the startup of the new pelleting line.

iv. Naphtha Analysis

In 1987 UCC's R&D department analyzed virtually every naphtha shipment that arrived at Taft to determine the composition of the naphtha. Naphtha is not a standard chemical, and different batches of naphtha could lead to different yields of ethylene and different degrees of coking. R&D analyzed the naphtha with a gas chromatograph and entered the results into a computer to predict the naphtha's yields, and this information was given to UCC's economics department to determine which naphtha shipments had the highest value.

f. Duration and Quantities of Product Produced

The MATRIC team provided Ms. Toivonen with the duration of the identified runs and the amount of products produced during the runs so that Ms. Toivonen could calculate the costs incurred in conducting those runs. As discussed in more detail below, Ms. Toivonen used duration to calculate the wage costs and the amount of product produced to calculate the material costs.

Where there was no explicit statement of the duration or the production quantity in the documentary evidence, the MATRIC team determined the amounts using a number of different methods. In

some cases the documents stated the pounds of material made during the run, and the MATRIC team calculated the duration by dividing the material by the operating rate in terms of pounds per hour. The MATRIC team determined the production rate from a number of different sources. If the operating rate was not known, the MATRIC team made estimates by looking at analogous tests or experiments.

Where neither the duration nor the quantity produced was explicitly stated on supporting documentation, the MATRIC team looked at similar runs and talked to people who actually conducted the experiments to obtain additional information. The MATRIC team then used its technical judgment to determine when a particular experiment began and ended. However, this was necessary for only a small percentage of the identified runs.

If the amount of product produced was not explicitly stated on the documentation but the raw materials were mentioned, the MATRIC team made estimates on yields or efficiencies based on information in the documents, its own knowledge, or information from interviewees. The MATRIC team used the data on the raw materials and its estimates on yields or efficiencies to calculate the amount of product made and then calculated duration using the amount of product made and the operating capacity or operating rate.

If the MATRIC team found a strategic run plan but not a run report, then it estimated the length of the run. The MATRIC team made these estimates on the basis of interviews with people who worked on the projects and data from analogous runs with the same technology. The names of the people who assisted the MATRIC team are not documented in the table of identified runs but are included in the interview notes. Other than with respect to the cable and wire business, Dr. Wadia did not check his production estimates against PCDs because the annual PCDs would show the entire quantity of the product produced in the year, not the quantity produced during the duration of the experiments.

In some cases the MATRIC team reported the duration of an identified run as shorter than the total duration of the activity. In those cases the MATRIC team included only the portion of the run that it determined related to experimentation. For example, if UCC personnel conducted experiments only between the time a run started and the time the unit reached a steady state, the MATRIC team included only the time required to reach a steady state in the duration of the identified run. If a run was conducted for the purpose of determining whether it would produce a product of acceptable quality, the MATRIC team treated the experimental portion of the run as ending when that determination was made. However, if the researchers continued to experiment after the unit reached a steady state, the MATRIC team would also

include the time when experimentation occurred in the total duration. In a small number of cases it was not clear when the experimental portion began or ended, and in those cases the MATRIC team made an estimate based on its knowledge, similar runs, and information from interviewees. The MATRIC team used the total run duration for most of the identified runs conducted in the polyolefins area because of the complexity of that area, but it frequently used a partial run duration for identified runs conducted in the industrial chemicals area where the systems are more predictable. The MATRIC team noted when it used a partial run duration in the comments section of the table of identified runs.

The MATRIC team also noted in the comments section of the table of identified runs when it made assumptions about run duration. According to the comments section, the MATRIC team made assumptions with respect to about 225 identified runs. We find that most of these assumptions were reasonable. However, the parties dispute the duration of the identified runs discussed below.

i. Natural and Forced Draft Burner Tests (Runs 1 through 11, 95, and 96)

Runs 1 through 11 involved tests on natural draft burners. Runs 95 and 96 involved tests on forced draft burners. UCC prepared a report for the natural draft burner tests and another report for the forced draft burner tests.

UCC conducted the tests on natural draft burners to determine the most energy efficient operating parameters for the furnaces. UCC collected data for runs 1 through 11 from January to October 1985.

UCC conducted runs 1 through 11 on nine furnaces equipped with natural draft burners (furnaces 1, 4, 5, 7, 9, 14, 15, 18, and 24[34]). UCC conducted an 11-point test on each of nine burners and also conducted additional tests on furnaces 9 and 15. It appears that Dr. Wadia determined that there were 11 runs by including one run for each of the nine furnaces and two additional runs for the second tests conducted on furnaces 9 and 15. However, Dr. Wadia did not distinguish between the 11 runs in his expert report.

The duration of each of the natural draft burner tests was reported in the natural draft burner report as 1 to 1-1/2 days. Dr. Wadia used the midpoint, 30 hours, as the duration of each of these runs. This was a conservative estimate because each of the 11 test points lasted about an hour, so the tests most likely occurred over 1-1/2 work days, not 24-hour days.

UCC also tested the effects of fuel specified gravity on energy use on furnace 9. UCC ran a 13-point test at three

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[34]As discussed below, natural draft burner tests were also conducted on furnaces 10 and 12, but those tests were conducted to collect baseline data for the forced draft burner tests in 1983, not as part of the natural draft burner tests that took place in 1985.

different gravities. The extra test points added approximately 2 hours to this test, but UCC could still reasonably complete the test within 30 hours.

The natural draft burner report refers to two separate 11-point tests conducted on furnace 15. During one test UCC collected data over a 23-hour period, and during the second UCC collected data over a 25-hour period. However, the engineer conducting the test would not typically collect data continuously over the entire test period.

The natural draft burner report also refers to the implementation of a new measurement technique called the Bunker-Ramo control technique. However, the technique was already well understood at that point, and UCC did not test or experiment with this technique as part of the natural draft burner tests.

Runs 95 and 96 were conducted on forced draft burners on furnaces 10 and 12 in 1984.[35] UCC installed the forced draft burners in early 1984 or late 1983. Before installing the new burners, UCC collected data from the natural draft burners on furnaces 10 and 12 to compare with data that UCC would collect after installing the new burners. We find that the tests on the natural draft burners on furnaces 10 and 12 occurred in late 1983. The natural draft burner tests conducted on Furnaces 10

[35]Dr. Wadia originally determined that runs 95 and 96 occurred in 1985 but corrected the date in his supplemental report. Respondent agrees that these runs occurred in 1984.

and 12 are not included in runs 1 through 11, 95, or 96 (or elsewhere on the table of identified runs).

The purpose of runs 95 and 96 was to measure the energy efficiency of the forced draft burners and compare the results with the tests on Furnaces 10 and 12 before the new burners were installed. UCC conducted two 11-point tests and one 7-point test on Furnace 10 during Run 95 and three 11-point tests on Furnace 12 during Run 96. Dr. Wadia determined that the durations of Runs 95 and 96 were 20 and 24 hours, respectively. Dr. Wadia believed this was a reasonable estimate because each point would take at least half an hour. The test data collected on Furnaces 10 and 12 with both the natural and forced draft burners were reported in the forced draft burner report.

The forced draft burner report also included data taken to measure NOx in order to aid UCC in complying with environmental regulations. The data was collected from Furnaces 10 and 12, which were fitted with forced draft burners at the time, and furnaces 3, 5, 6, 7, and 8, which were natural draft burners. To collect the data, UCC put an analyzer on the stack gas portion of the furnaces, which detected the amount of NOx floating up in the furnace. UCC did not make any changes to the furnaces outside the normal operating window. The purpose of collecting these data was to verify representations made by the burner vendors

regarding NOx production. Dr. Wadia did not include these data collection activities on the table of identified runs.

ii. Nalco 5211 Tests (Run 15)

Dr. Wadia identified two tests of a coke inhibitor known as Nalco 5211 as runs 15 and 566.[36] Run 15 was conducted on furnace 23 in Taft's Olefins-2 unit in 1986 and 1987. The overall purpose of the test was to determine the effectiveness of Nalco 5211 as a coking inhibitor. One objective of the test was to gather enough information to determine whether Nalco 5211 improved operations enough to justify the inhibitor's cost.

Dr. Wadia determined that run 15 lasted for 110 days, which is the amount of time that the furnace ran after Nalco 5211 was injected before the furnace was shut down. The test run ended prematurely because the furnace was upset. UCC predicted that the furnace would run for about 150 to 220 days if no upsets occurred.

According to the project report, the data collected after Nalco 5211 had been injected were compared to data collected from five base case runs on furnace 23 when no inhibitor had been injected and furnace 23 operated normally. A "base case" refers to the collection of data during normal operations to serve as a reference to compare to data collected during an experiment or

[36]The parties only dispute the duration of run 15. Accordingly, references to the Nalco 5211 test are only to run 15.

after an operational change has occurred. The five base case runs spanned 292 days from January to December 1985. The base case data were the same data normally collected by computer and would have been collected even if UCC did not intend to test Nalco 5211 on Furnace 23. An analysis of the base case data indicated that UCC's furnaces could run for 60 to 90 days between decokings under normal conditions without an inhibitor instead of 30 to 45 days as previously believed.

Following the test, UCC concluded that there was little economic incentive at Taft to justify the use of Nalco 5211 and that savings could be realized by extending the furnace run times without adding an inhibitor.

Dr. Wadia did not include the base case runs in his expert report because UCC did not change any process variables before the base case runs. Therefore, Dr. Wadia did not believe that they involved a process of experimentation. Ms. Toivonen, in her expert witness report, determined that the Nalco 5211 test cost $1,419,392.24 excluding the cost of the base case runs. Mr. Halle, one of respondent's expert witnesses, estimated that the base case runs would have cost about $5.4 million using Ms. Hinojosa's methodology for costing the Amoco anticoking project.

iii. Vinyl Acetate Catalyst Protection Tests (Runs 47 and 48 and Runs 594 and 596)

The vinyl acetate catalyst protection tests (runs 47 and 48) involved runs in the vinyl acetate unit. The goal of these runs was to protect the expensive catalyst from low levels of iodine, which comes in as an impurity with acetic acid. In run 47, a small (about a quarter of an inch) pilot tube was installed in the process stream to divert some of the feedstock to create a slipstream. UCC would then test the performance of a silver-containing resin for removing iodine from the acetic acid feed. The purpose of the run was to test the physical strength of the resin, which was being used as a trap bed for iodine, over a period of 2,400 hours to determine whether minor components in the acetic acid feed would have a deleterious effect on the resin.

For run 47 Dr. Wadia treated the experiment as having a duration of 12 hours, which was the time it took to set up and take down the apparatus and determine whether the material had maintained its physical integrity. Dr. Wadia did not count the 2,400 hours that the tube was in place as part of the test because there was no monitoring during that time. Furthermore, Dr. Wadia treated the product quantity as zero because the amount of feedstock going through the tube was so small compared to what

was going through the main process and it would be very difficult to quantify.

Run 48 was very similar to run 47 except that run 48 involved a larger tube and full-scale trap bed made of the same material. The purpose of Run 48 was similar to that of run 47 except that UCC also wanted to determine whether there would be other issues with scaling up the channeling.

For run 48 Dr. Wadia treated the duration as 720 hours, which was the time it would take to get a good indication of stability. The comment section on the table of identified runs does not provide any additional details as to how Dr. Wadia concluded that the duration of the run was 720 hours. Dr. Wadia did not include the entire duration of the run because the plant would have continued to operate as normal even if the experiment never happened.

Dr. Wadia again treated the production quantity as zero because the same materials that were used during run 48 were also being used in a simultaneous plant test of a new catalyst in the unit (Run 153) and Dr. Wadia did not believe that it was appropriate to double count the materials.

Dr. Wadia used the same methodology (including only the feedstock material flowing through the parts of the process in which the tests were being conducted) for runs 594 and 596, which also used a slipstream. Dr. Wadia used a duration of 216 and 96

hours for runs 594 and 596, respectively. Dr. Wadia determined that 3,000 and 3,800 pounds of products were produced during runs 594 and 596, respectively.

iv. Butyl Acetate Capacity Increase Test (Run 161)

UCC conducted the butyl acetate capacity increase test (run 161) to test an increase in butyl acetate production by increasing the number of refining column trays in the esters batch still. The trays were installed in January 1987 and removed in February 1987. Dr. Wadia treated the run as lasting 4 days even though the trays may have been in place for up to 2 months. Nothing in Dr. Wadia's expert reports explains how he determined this duration.

v. MEK Production Test (Run 175)

The MEK production test (run 175) involved the production of methyl ethyl keytone (MEK) at Institute from August 27 to October 5, 1988 (6 weeks). The production campaign responded to a severe market shortage of MEK. This run was UCC's first attempt to make MEK. According to the project report, UCC collected data for the first 914 hours of the run.

Dr. Wadia assumed that the startup and experimentation involved in the project took 2 weeks, and accordingly treated the duration as 336 hours. Nothing in Dr. Wadia's expert reports explains how Dr. Wadia arrived at the conclusion that the startup and experimentation took only 2 weeks.

vi. Secondary Refining System Test (Run 178)

The secondary refining system test (Run 178) involved a plant test conducted on the secondary refining system for the purpose of optimizing the ethanol refining system. The test involved feeding the primary extractive column overheads directly to the lights column to immediately separate acetaldehyde and ether from ethanol. The lights column tails were then fed to the secondary extractive column. The secondary refining system project lasted 2 weeks. However, Dr. Wadia assumed a duration of 1 week. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

vii. Spanish Fermentation Ethanol Refining Test (Run 180)

The Spanish fermentation ethanol refining test (run 180) involved the refining of Spanish fermentation ethanol with a goal of producing 200 proof ethanol. Dr. Wadia assumed a 4-day duration although about 11 days of testing were reported. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

viii. Ethanol Tertiary Recovery Test (Run 181)

The ethanol tertiary recovery test (run 181) was conducted for the purpose of optimizing the separation of propanol and the recovery of ethanol in the ethanol residue column. Dr. Wadia assumed a 4-day duration even though about 15 days of testing

were reported. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

ix. Mexican Fermentation Ethanol Refining Test (Run 184)

The Mexican fermentation ethanol refining test (run 184) involved the refining of Mexican fermentation ethanol with the goal of producing specification ethanol. Dr. Wadia assumed a 4-day duration although a 1-week test was reported. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

x. Propionic Acid Hydrogen Peroxide Treatment Test (Run 190)

The propionic acid hydrogen peroxide treatment test (run 190) involved the addition of small quantities of hydrogen peroxide to the process for making propionic acid. It began on February 18, 1987, and lasted 10 days. Dr. Wadia assumed a test period of 4 days. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

xi. Adiabatic Hydrogenation Beds Rearrangement Test (Run 198)

The adiabatic hydrogenation beds rearrangement test (run 198) involved rearranging the order of the adiabatic hydrogenation beds used to make butanol in order to improve product quality. The order was changed on February 29, 1984, and data were collected on March 21, 1984. Dr. Wadia determined that

the duration of run 198 was 4 days. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

xii. Butanol Refining Test (Run 202)

The butanol refining test (run 202) involved adjusting the base temperature on the butanol refining forecolumn. A 2-week test was reported, but Dr. Wadia determined a 4-day duration. Nothing in Dr. Wadia's expert reports explains how he arrived at this conclusion.

xiii. DIBK Recycle to Mixed Keytones Converters Test (Run 608)

The DIBK recycle to mixed keytones converters test (run 608) was a process enhancement test to suppress the formation of diisobutyl ketone (DIBK). The test was conducted between October 25 and November 23, 1988. However, Dr. Wadia determined that the portion of the test from November 1 to 8 demonstrated the catalyst performance and trends. Dr. Wadia does not explain in his expert reports how he chose November 1 and 8.

V. Base Period QREs

Ms. Toivonen, one of petitioner's expert witnesses, calculated the supply and wage costs UCC incurred in conducting the identified runs, including runs 807 through 820, which petitioner concedes occurred during the base period and constitute qualified research under section 41(d). Ms. Toivonen is a partner with the public accounting firm of Ernst & Young LLP

(E&Y). In performing her assignment Ms. Toivonen led a team of E&Y accounting professionals ranging from 10 to 75 people.

In addition, four current or former Dow/UCC cost accountants (including Ms. Hinojosa) assisted Ms. Toivonen in the costing process. Ms. Hinojosa and her colleagues identified the lead PCDs (the page of the PCD that is tied to the product produced in a specific run) and the MASs relating to the products Ms. Toivonen costed. Ms. Hinojosa also consulted on other issues.

As discussed above, Ms. Toivonen obtained the production quantities and run durations from the MATRIC team for runs 1 through 806. In situations where Dr. Wadia's production quantity exceeded the production quantity reflected on the lead PCD, Ms. Toivonen used Dr. Wadia's production quantity to calculate the cost of the run, to be conservative. Ms. Toivonen did not independently verify the MATRIC team's conclusions regarding run duration or production quantity, and the MATRIC team did not review Ms. Toivonen's costing of the identified runs.

Ms. Toivonen determined the run durations and production quantities for runs 807 through 820 using UCC's accounting records, not information provided by Dr. Wadia. Petitioner's counsel provided Ms. Toivonen with the accounting records that related to these runs. Ms. Toivonen did not have access to all of the technical documents produced in this case. However, when Ms. Toivonen felt that she needed additional documents, she asked

petitioner's counsel to see whether more information was available. Ms. Toivonen did not conduct an independent search for information relating to these runs because the Court directed Ms. Toivonen to rely on the factual record that existed at the end of the base period trial. Ms. Toivonen used historical UCC cost accounting records to calculate the costs of runs 807 to 815, 818, and 819. Ms. Toivonen used cost information supplied by CMAI to calculate the costs of runs 816, 817, and 820.

A. Documentation

During the base period, as in the credit years, UCC used the material accounting system for production, inventory, and product costing. Ms. Toivonen relied primarily upon PCDs and MASs to calculate the supply costs of the identified runs, which are the same types of documents that Ms. Hinojosa used to calculate the claimed QREs for the claim projects. Ms. Toivonen also used other records such as reports of UCC's third-party purchases and documents from UCC's latex business. Ms. Toivonen primarily used account levels and Star's performance history report to calculate wage costs. More than 90 percent of the base period cost calculations were based upon historical UCC accounting records. Ms. Toivonen and her team also used the MATRIC team's table of identified runs, a separate table prepared by the MATRIC team that listed the materials and material quantities used in the 140 latex runs identified by Dr. Wadia, historical pricing

information from CMAI regarding ethylene byproducts, and information provided by Dow/UCC cost accountants and Dow technical personnel.

Petitioner was unable to find its R&D budgets for 1984, 1985, 1986, 1988, 1994, or 1995. However, petitioner provided its R&D budgets for 1987.

B. Ms. Toivonen's Costing Methodology

To develop a methodology to calculate the costs UCC incurred in conducting the identified runs, Ms. Toivonen reviewed Ms. Hinojosa's expert report for the credit years and designed her methodology to be consistent with Ms. Hinojosa's methodology. Ms. Toivonen included the same types of costs and used the same types of records that Ms. Hinojosa used when it was possible. Ms. Toivonen's methodology involved:[37] (1) Identifying the lead PCDs for the runs; (2) identifying the materials that required costing; (3) tracing the materials through UCC's accounting records; (4) determining the unit costs of materials; (5) calculating the total materials costs; (6) calculating the wage costs; and (7) calculating the total run costs.

Following this process, Ms. Toivonen and her team prepared detailed cost calculations for each identified run. With certain

[37]As discussed above, some of these activities were performed by Ms. Hinojosa and her colleagues or the MATRIC team. In particular, Ms. Hinojosa identified the lead PCDs, and the MATRIC team determined the duration and production quantities for most of the identified runs.

exceptions discussed below, each identified run is supported by: (1) A lead PCD for the product or the closest match if the lead PCD was unavailable; (2) secondary PCDs and MASs used to derive the per-unit costs of internally produced materials used in the production of the lead PCD product; (3) an E&Y-generated unit cost calculation worksheet showing the actual unit cost calculation for each material used in the identified run; (4) an E&Y-generated material detail report showing the total cost of the materials used in producing the final product made in the identified run; (5) an E&Y-generated wage detail report showing the wage cost calculation for the identified run; and (6) an E&Y-generated summary report showing the total material and wage costs for the identified run. The supporting documentation was substantially similar for the identified runs conducted in UCC's latex business although the latex business did not use the same accounting records as the rest of UCC's C&P business.

1. Identifying the Lead PCD

As discussed above, Ms. Hinojosa identified the lead PCDs for the identified runs. A lead PCD provides the materials and material quantities used in manufacturing the final product(s) in a given year and essentially provides the "recipe" for making the product. Lead PCDs were not found for all of the products produced in the identified runs. If a lead PCD was not found for a specific product, Ms. Toivonen used a PCD for a similar

product. In other cases, Ms. Hinojosa identified more than one lead PCD that could have been a match for a run. In those cases, Ms. Toivonen selected the PCD that was the closest match.

2. Identifying the Materials

In a few cases Dr. Wadia identified materials used in a run that were different from the materials listed on the PCD. In such cases Ms. Toivonen relied on the PCD because it was UCC's official cost accounting record. As a result, Ms. Toivonen either would not cost the material identified by Dr. Wadia or would cost a material listed on the PCD that was different from the material identified by Dr. Wadia. Ms. Toivonen did not keep a list of materials that were identified by Dr. Wadia but that were not listed on the PCDs she used because she believed that materials would be omitted from UCC's cost accounting records only if their costs were immaterial.

Ms. Toivonen generally did not include utilities when she identified the materials that required costing. However, Ms. Toivonen did include the costs of the furnace gases and refrigeration used in the ethylene production process because Ms. Hinojosa included those costs when costing the claim projects that involved the ethylene production process.

3. Tracing the Materials

To calculate the unit cost of purchased materials, Ms. Toivonen divided the total material cost for the year by the

quantity received. The unit cost for internally produced materials was more complex. For internally produced materials the E&Y team identified the applicable secondary PCDs and traced all of the materials listed on the secondary PCDs. This tracing process was continued until the E&Y team reached the originating material purchases from third-party vendors. Internally produced materials frequently required multiple levels of tracing.

Ms. Toivonen and the E&Y team developed practical approaches to simplify the tracing process for internally produced materials. For example, where multiple levels of tracing were required, the tracing process was repeated until at least 80 percent of the total material quantity had been reached. The actual unit cost calculated from this material quantity was applied to the entire amount for the material used in an identified run. In some cases where an internally produced material accounted for less than 5 percent of the total cost shown on a lead PCD, Ms. Toivonen used UCC's annually updated material standard cost. These approaches did not materially affect the calculated cost of internally produced materials because the standard cost reasonably approximated UCC's actual per-unit cost.

4. Determining the Unit Costs of Materials

Transfer costs shown on lead PCDs represented materials transferred to the manufacturing site from another UCC division

or location. E&Y used MASs to determine the UCC division or location where the materials were originally purchased or produced. Other than the addition of freight or other charges, the unit cost calculation for transfer costs was the same for purchased and internally produced materials.

Consistent with Ms. Hinojosa's treatment of byproducts in calculating the costs of the claim projects, Ms. Toivonen and her team treated the costs of byproducts as reductions in the unit cost calculations. Actual per-unit byproduct costs were used where these costs had been previously determined. Otherwise, Ms. Toivonen used historical values from CMAI because that was the source of information that Ms. Hinojosa used for her claim project calculations. In a few instances where CMAI data were not available, Ms. Toivonen used UCC's standard cost. Where byproducts represented less than 5 percent of the total cost on a lead PCD, no reduction was taken because the impact on overall cost was immaterial.

During the base period, UCC both purchased and internally produced ethylene, which was a major raw material for many chemicals and plastics. Additional calculations were necessary to determine the actual unit cost of ethylene consumed in downstream products. Consistent with the methodology that Ms. Hinojosa used for the claim projects, Ms. Toivonen calculated a "Gulf Coast Weighted Average Pooled Price for Ethylene" using the

weighted average cost of UCC's ethylene purchases and internal production for each base period year.

Ms. Toivonen used a different approach to derive the unit costs of materials used in the 140 identified runs from UCC's latex business. The latex business did not use PCDs or MASs, and there were no accounting records for the base period for the latex business. Accordingly, Ms. Toivonen derived unit costs of the materials used in the latex runs from available latex business documents from other periods with adjustments for inflation where appropriate. For deionized water, which is a high-volume, low-dollar raw material, Ms. Toivonen used the UCC standard cost. Collectively, the 140 latex runs accounted for less than 1 percent of the total cost of the identified runs.

5. Calculating Total Materials Costs

Once Ms. Toivonen calculated the unit cost for each of the materials used to make the product produced during a run, Ms. Toivonen calculated the total materials cost for the product by multiplying the per-unit costs by the quantities of each material shown on the lead PCD (or on the MATRIC team's "Latex Run Batch Components Table" for the latex runs). This calculation generated the total production cost for the year for the product manufactured in the run. Ms. Toivonen then divided this total production cost for the product by the total quantity of the product produced in the year to generate a per-unit cost of the

product manufactured. Ms. Toivonen and the E&Y team then multiplied this per-unit cost by the quantity of product made during the identified run to determine the total material cost for the run. As discussed above, Ms. Toivonen obtained the production quantities from Dr. Wadia for runs 1 through 806.

6. Calculating the Wage Costs

Ms. Toivonen determined wage costs for each identified run by multiplying the run duration (supplied by Dr. Wadia) by a calculated hourly wage rate for the UCC manufacturing unit in which the run was conducted. Ms. Toivonen derived the hourly wage rates from account levels, which reported both budgeted and standard labor cost information for the budget accounts within UCC locations. Ms. Toivonen then adjusted the standard labor costs to actual costs by an allocation of the deviation accounts, which represent the differences between standard and actual labor costs. To calculate the hourly wage rates, Ms. Toivonen created “wage groups” based on common manufacturing areas at UCC plants. Ms. Toivonen then calculated “wage group dollars” based on the actual direct labor costs of each wage group as well as the allocable portion of shared laboratory and shift administration labor costs. Wage group dollars represented an aggregate cost of all employee-related wages and benefits associated with a UCC manufacturing unit. Ms. Toivonen calculated “wage group dollars

per production unit hour" by dividing wage group dollars by the wage group's total production unit hours.

The above methodology for calculating wages was used for all identified runs except for the latex runs and the runs conducted at Star between 1985 and 1988. Because account levels were not available for these runs, Ms. Toivonen estimated hourly wage rates on the basis of the best available information.

Ms. Toivonen determined that the total wage cost for all identified runs was approximately $7.937 million, or about 5.87 percent of the total run costs. For the claim projects, Ms. Hinojosa determined that wages accounted for only 1 percent of the total project costs. Furthermore, the wage rates for approximately 98 percent of the identified runs were higher than the wage rates used by Ms. Hinojosa. The reason for these differences was that Ms. Toivonen's approach to costing the identified runs was much more comprehensive than that used by Ms. Hinojosa and the records available for the base years were more detailed than those available for the credit years. In particular, budget reports were not available for the credit years. However, since Ms. Toivonen did not have data for wages paid at the Star plants for 1985 through 1988, she used the Star plant performance history report that was consistent with what Ms. Hinojosa used for the credit years. Furthermore, since Ms. Toivonen did not have accounting records for the latex business,

she estimated the wages for that business using information provided by the MATRIC team. The MATRIC team also calculated the run costs for the crystal products business because there were no accounting records available for that facility.

7. Calculating the Total Run Costs

Ms. Toivonen and the E&Y team then added the total materials cost to the total wage cost for each identified run to calculate the total cost of each identified run.

8. Exceptions to Ms. Toivonen's General Costing Methodology

Certain identified runs involved extraordinary situations requiring Ms. Toivonen and the E&Y team to develop and apply special costing rules.

The first exception was for sequential runs. When the manufactured product of an initial run was used as a material in a subsequent run, the costs of the manufactured product from the initial run were excluded from the second run calculation to avoid double counting.

Different treatment was also required for runs where third parties contributed materials at no charge. In these cases no cost was assigned to the contributed materials.

The next exception occurred when materials used to produce the manufactured product included some quantity of the same manufactured product that was treated as a work-in-process, such as recycled materials. In these cases the material quantity was

netted against the production quantity as shown on the lead PCD and the cost of the work-in-process material was excluded from the total cost on the PCD.

Ms. Toivonen calculated the cost of materials used in some ethylene furnace tests differently. The MATRIC team did not provide production quantities for some identified runs performed on ethylene furnaces because the ethylene was mass produced in multiple furnaces. In those cases, Ms. Toivonen calculated an hourly production rate for one furnace and multiplied the rate by the run duration as shown on the MATRIC table of identified runs.

Another exception was necessary when the PCDs for certain PE products made at Seadrift did not specify a nomenclatured resin but instead identified a generic “fluff” product. To identify the correct lead PCD for runs making these products, Ms. Toivonen used run-specific information such as the unit, density, comonomer, catalyst, and cocatalyst. Where there were multiple PCDs involving fluff resins with run-specific characteristics, Ms. Toivonen calculated a weighted average per-unit cost for the identified run from the PCDs.

Ms. Toivonen made an exception for the Oxo-12 LPO vaporizer capacity test (run 193) because the lead PCD reflected three manufactured products with two different units of measure. In addition, one manufactured product had a work-in-process material adjustment. Calculating a per-unit cost for the relevant

manufactured product required the quantity of the relevant product to be isolated on the PCD as a production quantity. One of the other manufactured products had to be recategorized as a byproduct, and the other had to be netted as a work-in-process material adjustment.

Ms. Toivonen also made an exception for identified runs where the lead PCD reported significant negative material quantities, resulting in a negative per-unit material cost. A negative per unit material cost was typically the result of UCC's reclassification of a material or some other adjustment. Ms. Toivonen corrected these quantities based on the forecasted contribution of the material to the standard cost shown on the PCD.

The next exception was for the crystal products business. UCC accounting records were not available for the crystal products business in Washougal, which was sold in the late 1990s. Accordingly, Ms. Toivonen and the E&Y team did not compute the cost of plant-based R&D activities for this business. The MATRIC team estimated that the cost of the identified runs conducted as part of the crystal products business (runs 687 through 691) was $472,000 per year.

Ms. Toivonen also used a different methodology for the runs conducted by Rohm & Haas before UCC acquired the Triton assets. Ms. Toivonen and the E&Y team determined material and labor costs

for the runs using Rohm & Haas documentation and made adjustments based on the Consumer Price Index, as published by the U.S. Department of Labor, Bureau of Labor Statistics.

The last exception was for identified runs where the table of identified runs did not report any production for the run. For those runs Ms. Toivonen obtained the materials and quantities consumed from the MATRIC team and then used the general costing methodology discussed above.

C. Ms. Toivonen's Conclusions

Ms. Toivonen concluded that, in her opinion, the total cost of all of the identified runs (the initial 793 identified runs and runs 807 through 820) for each base period year was as follows:

Year	Cost of Identified Runs
1984	$17,433,643
1985	22,837,583
1986	38,870,319
1987	22,396,571
1988	33,574,796
Total	135,112,912

D. Disputed Calculations

The parties dispute Ms. Toivonen's calculations of the following runs.[38] Accordingly, we discuss them below.

[38]Respondent also questions Ms. Toivonen's reliance on Dr. (continued...)

1. Acrolein Refining System Capacity Test (Run 128)

Dr. Wadia determined that UCC produced 1.8 million pounds of product in the acrolein refining system capacity test (run 128). However, Ms. Toivonen treated the production quantity as 90,000 pounds. Ms. Toivonen determined that the unit cost per pound was $0.16588 and accordingly calculated the total run material cost to be $14,929.27. Had Ms. Toivonen treated the run production quantity as 1.8 million pounds, the total run material cost would have been $298,584, a difference of $283,654.73. Ms. Toivonen testified that the discrepancy might be attributable to a unit of measure conversion, but she did not explain the discrepancy in her expert report.

2. Propyl Dipropasol Refining Test (Run 171)

Dr. Wadia listed sodium hydroxide as the catalyst for the propyl dipropasol refining test (run 171) on the table of identified runs. However, the PCD that Ms. Toivonen used to cost the run does not reference sodium hydroxide. Instead, the PCD lists sodium propylate as a raw material. Accordingly, Ms. Toivonen calculated the cost of sodium propylate instead of sodium hydroxide when costing the run.

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[38](...continued)
Wadia's determinations of the durations and production quantity for the runs discussed in sec. IV.B.3.f., above. However, because we have already discussed the facts relating to those runs, we need not address them again here.

Ms. Toivonen determined that the unit cost of sodium propylate for 1988 was $1.04607. For the cellosolve solvent test (run 576) Ms. Toivonen determined that the unit cost of sodium hydroxide pellets in 1985 was $0.2375 per pound.

3. Isophorone Mids Conversion Test (Run 173)

Dr. Wadia listed potassium carbonate as the catalyst for the isophorone mids conversion test (run 173) on the table of identified runs. Because potassium carbonate was not listed on the lead PCD for this run, Ms. Toivonen did not include the cost of potassium carbonate when she costed the run. According to a project report for the run, UCC used 15 gallons of potassium carbonate. Ms. Toivonen determined that potassium carbonate cost 34 cents to 95 cents per pound for other identified runs.

4. Secondary Refining System Test (Run 178)

Dr. Wadia's report states that part of the secondary refining system test (run 178) included a 2-day test with a caustic addition. However, Ms. Toivonen did not list any caustic additives as materials used in this run. The cost of caustic solutions in other runs ranged from 6 cents to 25 cents per pound.

5. Naphtha-Sulfur Injection Test (Run 807)

The naphtha-sulfur injection test involved the injection of naphtha into the production process. The purpose of the run was to determine whether the normal diethyl sulfide (DES) injection

could be replaced with naphtha in the gas feed to the cracking furnaces without causing problems to furnace operations or increasing carbon monoxide levels.

In costing the naphtha-sulfur injection test Ms. Toivonen did not include the costs of the equipment required to inject the naphtha. The equipment cost approximately $2,500 per furnace. Ms. Toivonen did not include the costs of the equipment because she considered those to be capital costs, not supplies or wages.

Ms. Toivonen also did not calculate the cost of naphtha as a separate material for the naphtha-sulfur injection test because the lead PCD did not list naphtha. However, the cost of the naphtha may have been captured on a secondary PCD which Ms. Toivonen used to calculate the costs of materials listed on lead PCDs. It is also possible that Ms. Toivonen included the cost of DES instead of naphtha, although DES is not listed on the lead PCD as a material used in the production of ethylene.

Ms. Toivonen determined that the naphtha-sulfur injection test lasted 35 days. The technical report for the test, written on January 20, 1986, states that the test began on December 16, 1985. Ms. Toivonen allowed 1 day for preparation of the report.

6. Methylmercaptopropanal (MMP) Refrigeration Tests (Run 810)

Run 810 consisted of two MMP refrigeration capacity tests. The first test was designed to evaluate transfer chiller control at negative 10 degrees Centigrade instead of negative 17 degrees

Centigrade as a means to minimize super-cooling, which could cause MMP to freeze or hydrates to form. The second test was designed to estimate the ambient heat gain of the day tanks and storage tanks as a means to verify assumptions that UCC's engineering division used in calculations.

Ms. Toivonen did not include any utility costs in the cost of the MMP refrigeration tests. Ms. Toivonen determined that utility costs should not be included in the cost of the run because Ms. Hinojosa generally excluded utility costs unless they were extraordinary. Ms. Hinojosa found utility costs to be extraordinary only in the production of ethylene. Accordingly, Ms. Toivonen considered electricity to be an extraordinary cost only when a run involved the production of ethylene. In other situations, Ms. Toivonen did not calculate the cost of electricity because it was not captured in UCC's accounting records. Accordingly, Ms. Toivonen had no basis for determining whether the cost of electricity was extraordinary.

OPINION

The research credit was introduced with the enactment of the Economic Recovery Tax Act of 1981, Pub. L. 97-34, sec. 221(a), 95 Stat. 241.[39] Congress enacted the research credit to "stimulate a higher rate of capital formation and to increase productivity", S. Rept. 97-144, at 76-77 (1981), 1981-2 C.B. 412, 438-439; H.

[39]The research credit was originally included in sec. 44F.

Rept. 97-201, at 111 (1981), 1981-2 C.B. 352, 358, and "to encourage business firms to perform the research necessary to increase the innovative qualities and efficiency of the U.S. economy." S. Rept. 99-313, at 694 (1986), 1986-3 C.B. (Vol. 3) 1, 694; H. Rept. 99-426, at 177 (1985), 1986-3 C.B. (Vol. 2) 1, 177. Congress found research to be essential to America's economic progress and competitiveness. H. Conf. Rept. 100-1104, at 88 (1988), 1988-3 C.B. 473-578.

However, in 1986 Congress became concerned that taxpayers were interpreting the research credit too broadly and that "some taxpayers * * * claimed the credit for virtually any expenses relating to product development." S. Rept. 99-313, supra at 694-695, 1986-3 C.B. (Vol. 3) at 694-695; see also H. Rept. 99-426, supra at 178, 1986-3 C.B. (Vol. 2) at 178. Therefore, Congress amended the research credit by the Tax Reform Act of 1986, Pub. L. 99-514, sec. 231(b), 100 Stat. 2173, to provide a definition of "qualified research".

The research credit was intended to apply to incremental research and experimental expenditures in order to overcome the resistence of businesses to bearing the costs that must be incurred to initiate or expand research programs. H. Rept. 97-201, supra at 111, 1981-2 C.B. at 358; see also Staff of Joint Comm. on Taxation, General Explanation of the Economic Recovery Tax Act of 1981, at 119-120 (J. Comm. Print 1981) ("The new

credit applies only to increases in qualified research expenditures, in order to encourage enlarged research efforts by companies which already may be engaged in some research activities.”). The goal of the research credit was to encourage research activity that would not otherwise have been undertaken. 135 Cong. Rec. S13114, S13125 (daily ed. Oct. 12, 1989) (Senate Finance Committee Report on Title VI, Revenue Reconciliation Act of 1989, Subtitle A., Extensions of Certain Expiring Tax Provisions).

Section 41(a)(1) allows taxpayers a credit against income taxes in an amount equal to 20 percent of the excess (if any) of the taxpayer’s QREs for the year over the base amount.[40] To determine the amount of a taxpayer’s QREs, the taxpayer must determine whether any of its activities constitute “qualified research” as defined in section 41(d), and then determine which costs attributable to the qualified research constitute QREs under section 41(b). QREs include in-house research expenses and contract research expenses. Sec. 41(b)(1).

The base amount is generally the product of the fixed-base percentage and the average annual gross receipts of the taxpayer for the 4 years preceding the credit year. Sec. 41(c)(2). The fixed-base percentage is normally the lesser of 16 percent or the

[40]Sec. 41(a)(2) does not apply in this case. Sec. 41(a)(3) was added in 2005. Energy Policy Act of 1985, Pub.L. 109-58, sec. 1351(a)(1), 119 Stat. 594, 1056.

percentage that the aggregate QREs of the taxpayer for the taxable years beginning in the years 1984 through 1988 (the base period) is of the aggregate gross receipts of the taxpayer for those years. Sec. 41(c)(3)(A). However, the base amount may not be less than 50 percent of the QREs for the credit year. Sec. 41(c)(2). The parties do not dispute the amount of UCC's annual gross receipts for the 4 years preceding the credit years or for the base period. Accordingly, we need only determine the amount of UCC's additional QREs for the base period to be able to recalculate the base amount.

A taxpayer must determine its QREs to be taken into account in computing its fixed-base percentage "on a basis consistent with" its determination of QREs for the credit year (the consistency requirement). Sec. 41(c)(4).[41] Accordingly, the taxpayer must include the same types of activities from the credit year and the base period when identifying qualified research activities and include the same types of costs as QREs for the credit year and the base period.

Respondent argues that petitioner has failed to prove that any of the claim projects constitute qualified research within the meaning of section 41(d). Even if some of the claim projects

[41]In 1996 the consistency requirement was redesignated subsec. (c)(5). Small Business Job Protection Act of 1996, Pub. L. 104-188, sec. 1204(c), 110 Stat. 1774. In 2006 the consistency rule again was redesignated subsec. (c)(6). Tax Relief and Health Care Act of 2006, Pub. L. 109-432, div. A, sec. 104(c)(1), 120 Stat. 2935.

constitute qualified research, respondent also argues that petitioner has not satisfied the consistency requirement because it has not proved that it included all similar activities in its base period computations. Respondent further argues that even if petitioner has satisfied these requirements, it has not established that it incurred any additional QREs not already taken into account for the credit years because petitioner is claiming production costs as QREs. To the extent that petitioner has incurred additional credit year QREs, respondent argues that petitioner failed to establish that it used a consistent method to calculate its revised base period QREs. Respondent also argues that petitioner failed to substantiate its credit year and base period activities, made unreliable assumptions and estimations to calculate its claimed credits, and asks the Court to rely on conclusory opinions of its expert. We address these arguments in turn.

I. The Experts

Both parties rely on expert opinions to support their arguments. We evaluate expert opinions in the light of all of the evidence in the record, and we are not bound by the opinion of any expert witness. Helvering v. Natl. Grocery Co., 304 U.S. 282, 295 (1938); Shepherd v. Commissioner, 115 T.C. 376 (2000), affd. 283 F.3d 1258 (11th Cir. 2002). We may reject, in whole or

in part, any expert opinion. Estate of Davis v. Commissioner, 110 T.C. 530, 538 (1998).

A. Petitioner's Expert Witnesses

1. Peter Spitz

Petitioner introduced expert testimony by Peter Spitz regarding the role of plant-based research. Mr. Spitz is a chemical engineer who has written two books on the petrochemical industry, consulted for petrochemical companies for several decades, and testified as an expert witness regarding the role of plant-scale R&D for petrochemicals.

2. Gilbert Froment

Petitioner introduced expert testimony by Gilbert Froment regarding the Amoco anticoking project. Dr. Froment is a professor of chemical engineering at Texas A&M University with about 50 years of experience teaching and consulting in the field of thermal cracking for olefins production. He has written at least 70 scientific papers dedicated to issues in olefins production, and several of these papers specifically related to coke formation and its consequences. Dr. Froment is a member of several professional associations and has designed thermal cracking pilot plants in which he has led studies of coke formation and its consequences.

3. Richard Martin

Petitioner introduced expert testimony by Richard Martin regarding the spuds project. Dr. Martin has over 30 years of experience developing, designing, and testing combustion equipment for the refining and petrochemical industries. Dr. Martin was previously employed by the John Zink Co. and was involved in the development and testing of the radiant wall burners that are currently installed in the furnaces used in Taft's Olefins-2 unit.

4. Norman Brockmeier

Petitioner introduced expert testimony by Norman Brockmeier regarding the UCAT-J commercialization program conducted at Star in general and the UCAT-J project that took place during the credit years in particular. Dr. Brockmeier is a licensed professional engineer, president of Oakwood Consulting, Inc., and a Fellow of the AIChE. He has more than 40 years of industrial experience. His specialty is polyolefin process design and catalysis, and he has many publications and design projects in this field.

5. Ms. Hinojosa

Ms. Hinojosa, a former cost accountant for UCC and currently an accountant for Dow, calculated the costs of the supplies and wages that petitioner claims as QREs in conducting the claim projects. At trial Ms. Hinojosa was qualified as an expert in

the accounting systems and documentation employed by UCC during the credit years and the base period.

6. Dr. Wadia

Dr. Wadia was qualified in the base period trial as an expert in conducting R&D related to the manufacturing of chemicals and plastics. Dr. Wadia has a doctorate of science and a master's degree in chemical engineering from the Massachusetts Institute of Technology. Dr. Wadia held a variety of technical and senior management positions in business and corporate R&D, technology licensing, and engineering over approximately 30 years with UCC and Dow.

7. Ms. Toivonen

Ms. Toivonen is a certified public accountant and partner with E&Y. During the base period trial Ms. Toivonen was qualified as an expert in accounting. Ms. Toivonen's specialty is forensic accounting, a practice that involves the application of accounting, auditing, and investigative skills to analyze a company's financial records.

B. Respondent's Expert Witnesses

1. Roy T. Halle

Respondent introduced expert testimony by Roy T. Halle regarding the Amoco anticoking, sodium borohydride, and UOP GA-155 projects as well as some of the identified runs that occurred during the base period. Mr. Halle has over 45 years of

experience in the petrochemical and petroleum industries, mostly in the olefins industry. For the past 10 years, Mr. Halle has worked as an independent consultant on olefins manufacturing process issues. Mr. Halle is an affiliate of LECG, L.L.C. (LEGC), in the area of petroleum and petrochemicals.

2. M. Julianne McClung

Respondent introduced expert testimony by M. Julianne McClung regarding the spuds project. Ms. McClung, like Mr. Halle, is an affiliate of LECG. Ms. McClung has over 11 years of experience working with the steam-cracking area of an ethylene plant, during which she was involved in all areas of maintaining, operating, and designing a steam-cracking furnace.

3. Gary Allen

Respondent introduced expert testimony by Gary Allen regarding the UCAT-J project. Dr. Allen is an affiliate of the petroleum and chemicals practice of LECG. He has over 30 years of experience in the chemicals and plastics industry. Dr. Allen led the development and commercialization of several different polymer technologies. Respondent introduced Dr. Allen as an expert in scaling up chemical and process technologies to commercial operations. While Dr. Allen conceded that he has less experience with PE, polyolefins, and UNIPOL than petitioner’s fact witnesses, Dr. Allen has extensive experience scaling up

products and processes from laboratories through pilot plants to commercial manufacturers.

II. Whether the Claim Projects Constitute Qualified Research

A. The Qualified Research Tests

To be eligible for a credit under section 41(a)(1) a taxpayer must show that it has performed "qualified research" during the years at issue. Sec. 41(a)(1)(A), (b)(2). To be qualified research, the research must satisfy four tests. First, expenditures connected with the research must be eligible for treatment as expenses under section 174 (the section 174 test). Sec. 41(d)(1)(A). Second, the research must be undertaken for the purpose of discovering technological information (the technological information test[42]). Sec. 41(d)(1)(B)(i). Third,

[42]We have previously called this test the "discovery test". See Norwest Corp. & Subs. v Commissioner, 110 T.C. 454, 491 (1998); Eustace v. Commissioner, T.C. Memo. 2001-66, affd. 312 F.3d 905 (7th Cir. 2002). Before the promulgation of sec. 1.41-4(a)(3)(ii), Income Tax Regs., we held that this test had a "discovery" component that was to be construed more narrowly than the discovery test of sec. 174 and required that the taxpayer discover information that went beyond the current state of knowledge in the relevant field. Norwest Corp. & Subs. v. Commissioner, supra at 493; Eustace v. Commissioner, supra. However, the current regulations provide that "A determination that research is undertaken for the purpose of discovering information that is technological in nature does not require the taxpayer be seeking to obtain information that exceeds, expands or refines the common knowledge of skilled professionals in the particular field of science or engineering in which the taxpayer is performing the research." While these regulations apply to years ending on or after Dec. 31, 2003, sec. 1.41-4(e), Income Tax Regs., respondent has taken the position that he will not challenge return positions that are consistent with these final regulations and therefore that the current regulation should

(continued...)

the taxpayer must intend that the information to be discovered will be useful in the development of a new or improved business component of the taxpayer (the business component test). Sec. 41(d)(1)(B)(ii). Fourth, substantially all of the research activities must constitute elements of a process of experimentation for a purpose relating to a new or improved function, performance, reliability, or quality (the process of experimentation test). Sec. 41(d)(1)(C), (3).

The Department of the Treasury (Treasury) and the Internal Revenue Service (IRS) promulgated regulations to clarify the definition of "qualified research" under section 41(d) that are effective for taxable years ending on or after December 31, 2003. Because the Treasury Decision implementing these regulations states that "the IRS will not challenge return positions that are consistent with these final regulations" for taxable years ending before the effective date of this regulation, T.D. 9104, 2004-1 C.B. 406, 410, and respondent conceded that petitioner may rely on the current regulations, we will not hold petitioner to a higher standard than the regulations require.

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[42](...continued)
govern the outcome of this case, see T.D. 9104, 2004-1 C.B. 406, 410. Accordingly, respondent concedes that petitioner satisfies the "technological in nature" test as long as the information sought to be discovered is in fact technological, and we accept this concession. In light of the change to the test, we find that it is more appropriate to refer to this test as the "technological information test".

The above tests are applied separately to each business component. Sec. 41(d)(2)(A). A "business component" includes, in pertinent part, a product or process that the taxpayer either holds for sale, lease, or license or uses in its trade or business. Sec. 41(d)(2)(B). In the case of a production process, section 41(d)(2)(C) provides that "Any plant process, machinery, or technique for commercial production of a business component shall be treated as a separate business component (and not as part of the business component being produced)."

The claim projects all relate to UCC's processes for commercial production of ethylene, PE, or related products. Accordingly, each of the claim projects includes two business components: (1) The production process and (2) the product being produced. Petitioner argues that for each claim project it is one of UCC's processes, not the product produced, that is the relevant business component. Therefore, in order to analyze the discrete business components at issue, for each project we must separate the activities that relate to the improvement of the production process from the activities that relate to the product being produced. Sec. 1.41-4(b)(1), Income Tax Regs. The fact that activities that relate to the product being produced do not satisfy the qualified research tests of section 41(d) will have no impact on whether the activities that relate to the improvement of the production process satisfy those tests.

If a business component as a whole fails the qualified research tests, we may apply the "shrinking-back rule", which allows us to apply the qualified research tests to subsets of the business component if doing so will allow the subset to satisfy those tests. Sec. 1.41-4(b)(2), Income Tax Regs. The shrinking-back rule provides that if the qualified research tests are not satisfied at the level of the discrete business component, they are then applied to the most significant subset of elements of the business component. The shrinking-back continues until either a subset of the business component satisfies the tests or the most basic element of the business component is reached and fails to satisfy the tests. The shrinking-back rule applies only if the overall business component does not satisfy the qualified research tests set out in section 41(d)(1) and is not itself a reason to exclude activities from credit eligibility. Id.

1. The Section 174 Test

The section 174 test requires that expenditures connected with the research activities must be eligible for treatment as expenses under section 174. Section 174 provides alternative methods of accounting for "research or experimental expenditures" that taxpayers would otherwise capitalize. Sec. 1.174-1, Income Tax Regs. The regulations define "research or experimental expenditures" as "expenditures incurred in connection with the taxpayer's trade or business which represent research and

development costs in the experimental or laboratory sense." Sec. 1.174-2(a)(1), Income Tax Regs.[43] The parties do not dispute that costs of the claim projects were incurred in connection with UCC's trade or business. As relevant here, an activity is "research and development * * * in the experimental or laboratory sense" if: (1) The information available to the taxpayer does not establish the capability or method for developing or improving a product or process or the appropriate design of a product or process (i.e., an uncertainty exists); and (2) the activity is intended to discover information that would eliminate this uncertainty. Sec. 1.174-2(a)(1) and (2), Income Tax Regs. Because the taxpayer need only be uncertain as to "the capability or method * * * or the appropriate design" of the improvement, an uncertainty may exist even if the taxpayer knows that it is technically possible to achieve a goal but is uncertain of the method or appropriate design to use to reach that goal. Sec. 1.174-2(a)(1), Income Tax Regs. (emphasis added). Whether an

[43]While the current version of these regulations applies to years beginning after Oct. 3, 1994, the Treasury Decision accompanying the current regulations states: "Because the amendments merely clarify the existing definition of research or experimental expenditures, retroactive application of the amendments is unnecessary. Return positions consistent with the amendments will be consistent with the existing regulations and will be recognized as such by the IRS." T.D. 8562, 1994-2 C.B. 30, 31. Respondent concedes that petitioner may rely on the current version of the regulations to determine whether the claim projects carried out in 1994 constitute qualified research.

uncertainty exists is an objective test that depends on the information available to the taxpayer. See Mayrath v. Commissioner, 41 T.C. 582, 590-591 (1964), affd. 357 F.2d 209 (5th Cir. 1966). These guidelines apply to the nature of the activity examined, not the nature of or the level of technological advancement represented by the product or process. Sec. 1.174-2(a)(1) and (2), Income Tax Regs.

However, deductions are allowed under section 174 only to the extent that they are reasonable. Sec. 174(e). Furthermore, deductions under section 174 are limited to "expenditures of an investigative nature expended in developing the concept of a model or product", as opposed to the construction or manufacture of the product itself. Mayrath v. Commissioner, supra at 590; Glassley v. Commissioner, T.C. Memo. 1996-206; Kollsman Instrument Corp. v. Commissioner, T.C. Memo. 1986-66, affd. 870 F.2d 89 (2d Cir. 1989). Therefore, if a project involves both the development of the concept of a new or improved process and the use of the process in production, only the activities related to the development of the concept of the process satisfy the section 174 test.

The regulations under section 174 exclude expenditures for certain activities, including, as relevant here, the ordinary testing or inspection of materials, products, or processes for quality control (quality control testing). Sec. 1.174-2(a)(2)

and (3), Income Tax Regs. Quality control testing includes testing or inspecting to determine whether particular units of materials, products, or processes conform to specified parameters. Sec. 1.174-2(a)(2) and (3), Income Tax Regs. However, quality control testing does not include testing to determine whether the design of the product or process is appropriate. Sec. 1.174-2(a)(2), (3), and (4), Income Tax Regs.

Because section 174 refers to research and experimental expenditures, not research and experimental activities, we interpret section 41(d)(1)(A) as requiring only that qualified research activities constitute research and development within the meaning of section 174. However, as discussed below, to determine which costs of those activities constitute QREs under section 41(b), the reference to section 174 in section 41(d)(1)(A) requires us to consider whether those costs may be treated as expenses under section 174. See Norwest Corp. & Subs. v. Commissioner, 110 T.C. 454, 491 (1998).

2. The Technological Information Test

The technological information test requires that the research be undertaken for the purpose of discovering information that is "technological in nature". Sec. 41(d)(1)(B)(i). Information is "technological in nature" if it "fundamentally relies on principles of the physical or biological sciences, engineering, or computer science". H. Conf. Rept. 99-841 (Vol.

II), at II-71 through II-72 (1986), 1986-3 C.B. (Vol. 4) 1, 71-72. Therefore, discovery of information related to the social sciences, arts, or humanities would not satisfy this test. Norwest Corp. & Subs. v. Commissioner, supra at 492.

3. The Business Component Test

The business component test requires that the taxpayer intend that the information to be discovered be useful in the development of a new or improved business component of the taxpayer. Sec. 41(d)(1)(B)(ii). To be useful within the meaning of this test, the research need only provide some level of functional improvement to the taxpayer. Norwest Corp. & Subs. v. Commissioner, supra at 495.

4. The Process of Experimentation Test

The process of experimentation test has three elements: (1) Substantially all of the research activities must constitute (2) elements of a process of experimentation (3) for a qualified purpose. Sec. 41(d)(1)(C).

The "substantially all" element means that 80 percent or more of the taxpayer's research activities for each business component, measured on a cost or other consistently applied reasonable basis, must constitute a process of experimentation for a qualified purpose. Norwest Corp. & Subs. v. Commissioner, supra at 497; sec. 1.41-4(a)(6), Income Tax Regs. A taxpayer does not fail this requirement even if the remaining 20 percent

(or less) of its research activities with respect to the business component do not constitute elements of a process of experimentation for a purpose described in section 41(d)(3) as long as the remaining research activities satisfy the requirements of section 41(d)(1)(A) (the section 174 test) and are not otherwise excluded under section 41(d)(4). Sec. 1.41-4(a)(6), Income Tax Regs. If a business component fails the process of experimentation test because of the "substantially all" requirement, the taxpayer may apply the shrinking-back rule, discussed above, until an element that satisfies the test is reached. Norwest Corp. & Subs. v. Commissioner, supra at 497.

A process of experimentation is "a process designed to evaluate one or more alternatives to achieve a result where the capability or the method of achieving that result, or the appropriate design of that result, is uncertain as of the beginning of the taxpayer's research activities." Sec. 1.41-4(a)(5)(i), Income Tax Regs. The "uncertainty" element of this test is essentially the same uncertainty as is required by the section 174 test,[44] and the test may be satisfied even if the taxpayer is certain of either the capability or method of achieving the desired goal if the appropriate design of the desired result is uncertain at the outset. Sec. 1.41-4(a)(5)(i),

[44]Sec. 1.174-2(a)(1), Income Tax Regs., provides that "Uncertainty exists if the information available to the taxpayer does not establish the capability or method for developing or improving the product or the appropriate design of the product."

Income Tax Regs.; cf. Norwest Corp. & Subs. v. Commissioner, supra at 496.[45]

However, this test also imposes a more structured method of discovering information than section 174 requires and may not include all actions a taxpayer takes to resolve uncertainty. See Norwest Corp. & Subs. v. Commissioner, supra at 496; see also Eustace v. Commissioner, 312 F.3d 905, 907 (7th Cir. 2002), affg. T.C. Memo. 2001-66. The process of experimentation test was added to section 41 because Congress was concerned that taxpayers had been claiming the credit "for virtually any expenses relating to product development" as opposed to high technology. S. Rept. 99-313, supra at 694-695, 1986-3 C.B. (Vol. 3) at 694-695; see also H. Rept. 99-426, supra at 178, 1986-3 C.B. (Vol. 2) at 178. The process of experimentation test is not necessarily satisfied just because a taxpayer takes steps to improve a business component. The legislative history explains:

> The term process of experimentation means a process involving the evaluation of more than one alternative designed to achieve a result where the means of achieving that result is uncertain at the outset. This may involve developing one or more hypotheses, testing and analyzing those hypotheses (through, for example, modeling or simulation), and refining or discarding the hypotheses as part of a sequential design process to develop the overall component.

[45]As discussed above, we shall apply the more generous rule of the final regulations where it differs from our prior holdings.

> Thus, for example, costs of developing a new or improved business component are not eligible for the credit if the method of reaching the desired objective (the new or improved product characteristics) is readily discernible and applicable as of the beginning of the research activities, so that true experimentation in the scientific or laboratory sense would not have to be undertaken to develop, test, and choose among viable alternatives. On the other hand, costs of experiments undertaken by chemists or physicians in developing and testing a new drug are eligible for the credit because the researchers are engaged in scientific experimentation. Similarly, engineers who design a new computer system, or who design improved or new integrated circuits for use in computer or other electronic products, are engaged in qualified research because the design of those items is uncertain at the outset and can only be determined through a process of experimentation relating to specific design hypotheses and decisions as described above. [H. Conf. Rept. 99-841 (Vol. II), supra at II-72, 1986-3 C.B. (Vol. 4) at 72.]

This requires the use of the scientific method sense, not merely taking steps to resolve uncertainty or to improve a product. See Black's Law Dictionary (8th ed. 2004) (defining the "scientific method" as "An analytical technique by which a hypothesis is formulated and then systematically tested through observation and experimentation."). To satisfy the process of experimentation test, the taxpayer should develop a hypothesis as to how a new alternative might be used to develop a business component, test that hypothesis in a scientific manner, analyze the results of the test, and then either refine the hypothesis or discard it and develop a new hypothesis and repeat the previous steps.

It is not sufficient that the taxpayer use a method of simple trial and error to validate that a process or product

change meets the taxpayer's needs. See id. While the Commissioner concedes in the regulations that a "systematic trial and error methodology" can be a process of experimentation, sec. 1.41-4(a)(5)(i), Income Tax Regs., the term "systematic" suggests that the project must involve a methodical plan involving a series of trials to test a hypothesis, analyze the data, refine the hypothesis, and retest the hypothesis so that it constitutes experimentation in the scientific sense. Testing and refining a hypothesis may involve determining the strengths and weakness of the alternative tested, whether and how the process could be further refined and improved, and whether other alternatives might be better suited for achieving the taxpayer's goal. While the process of experimentation need identify only one alternative, it generally should be capable of evaluating more than one alternative. Sec. 1.41-4(a)(5)(i), Income Tax Regs. If only one alternative is tested, for that alternative to constitute a process of experimentation the taxpayer should conduct a series of experiments with the alternative in order to develop the business component. See H. Conf. Rept. 99-841 (Vol. II), supra at II-72, 1986-3 C.B. (Vol. 4) at 72.

In response to commentary that "in the industrial or commercial setting, the recording of results is not necessarily inherent in a bona fide process of experimentation", Treasury and the IRS acknowledged that the regulations in place during the

years at issue did not impose any rules regarding the recording of experiment results. T.D. 8930, 2001-1 C.B. 433, 437. However, even if the results are not actually recorded, the taxpayer should perform a sufficient analysis of the alternative tested so that the taxpayer could meaningfully compare one alternative to another. Furthermore, section 1.41-4(d), Income Tax Regs., requires a taxpayer to "retain records in sufficiently usable form and detail to substantiate that the expenditures claimed are eligible for the credit."

The qualified purposes are purposes relating to a new or improved function, performance, reliability, or quality. Sec. 41(d)(3). By contrast, style, taste, cosmetic, or seasonal design factors are not qualified purposes. Sec. 41(d)(3)(B).

5. Activities That Are Not Qualified Research

Section 41(d)(4) lists certain activities that do not constitute qualified research, including, as relevant here: (1) Research after commercial production, (2) routine data collection, (3) foreign research, and (4) funded research.

Research conducted after the beginning of commercial production is not qualified research. Sec. 41(d)(4)(A). A business component is ready for commercial production when it is developed to the point where it: (1) Meets the basic functional and economic requirements of the taxpayer; or (2) is ready for commercial sale or use. H. Conf. Rept. 99-841 (Vol. II), supra

at II-74, 1986-3 C.B. (Vol. 4) at 74. Typical examples of activities conducted after commercial production include: (1) Preproduction planning for a finished business component; (2) tooling-up for production; (3) trial production runs; (4) trouble-shooting involving detecting faults in production equipment or processes; (5) accumulation of data relating to production processes; and (6) debugging product flaws. Id. at II-74 through II-75, 1986-3 C.B. (Vol. 4) at 74-75. The exclusion for research after commercial production applies separately to the activities relating to the development of the product and the activities relating to the development of the process. Sec. 1.41-4(c)(2)(iii), Income Tax Regs. Therefore, even after a product is ready for commercial sale, activities relating to the development of the manufacturing process may constitute qualified research.

Funded research refers to research to the extent it is funded by any grant, contract, or otherwise by another person or governmental entity. Sec. 41(d)(4)(H).

B. The Claim Projects

1. Plant-Based Research

All of the claim projects took place at UCC's manufacturing plants during the production process. Petitioner argues that as a general matter, plant-based research can be "qualified research". Mr. Spitz, one of petitioner's expert witnesses,

testified that petrochemical chemical companies carry out plant-scale R&D for many reasons, such as developing new process technologies and products, enhancing the performance of existing process technologies and products, and attempting to resolve operational problems. Mr. Spitz believes that it is essential for petrochemical companies to conduct research at commercial plants to obtain meaningful test data. In Mr. Spitz's opinion, experiments conducted in laboratories or pilot plants cannot simply be "scaled-up" to full-sized plants without additional testing because of the differences in size, dimensions, and fluid dynamics of plant equipment and the inherent unpredictability of chemical reactions and chemical plant operations.

Petitioner argues that making plant-based research eligible for the research credit comports with Congress' intent to promote business research in order to spur economic growth. Furthermore, petitioner argues that Congress could not have intended to foreclose availability of the credit for research that is helpful to a taxpayer's trade or business because the research was conducted in a plant environment and the research resulted in salable products.

Respondent agrees that plant-based research satisfying section 41(d) is eligible for the research credit. However, respondent argues that all of the claim projects fail the qualified research tests because the activities involved in the

claim projects were primarily production activities, not investigative activities related to developing the concept of the process, and therefore fail the section 174 test under Mayrath v. Commissioner, 41 T.C. at 590. Respondent argues that the claim projects also fail the section 174 test because they were designed to produce products for sale, not to eliminate any uncertainties. Furthermore, respondent argues that all of the claim projects fail the process of experimentation test because substantially all of the activities for which petitioner is claiming QREs constituted production activities, not elements of a process of experimentation. Respondent also argues that the claim projects involve research after the beginning of commercial production and therefore are excluded under section 41(d)(4)(A).

Petitioner argues that respondent incorrectly identified the end products produced by UCC, not the techniques and processes UCC employed to produce those products, as the "business component" to which the research relates. While the products produced during the claim projects already met UCC's basic functional and economic requirements, petitioner argues that the processes were still experimental and had not yet been proven.

As discussed above, under section 41(d)(2)(C) plant processes for commercial production are treated as a separate business component from the product being produced. Accordingly, where a taxpayer seeks research credits for plant processes but

not for the products produced, we apply the qualified research tests only to activities related to the development of the process without taking into account the activities related to the production or development of the product. Sec. 1.41-4(b)(1), Income Tax Regs. While each of the claim projects in its entirety necessarily involves production activities because the goal of each of the claim projects was to improve UCC's production process, we find that for each of the claim projects there are two business components: (1) A process business component and (2) a product business component. The activities that relate primarily to the improvement of UCC's processes are part of the process business component, and the activities that relate primarily to the production of products are part of the product business component. Therefore, respondent's arguments that petitioner's production activities do not satisfy the section 174 test or the process of experimentation test have no bearing on whether the activities that relate primarily to the development of UCC's processes satisfy the qualified research tests.

2. The Amoco Anticoking Project

Petitioner claims that the Amoco anticoking project constitutes qualified research and the specific business component at issue is the olefins production process. As discussed above, under section 41(d)(2)(C) and section 1.41-

4(b)(1), Income Tax Regs., we find that only activities that relate to the improvement of UCC's olefins production process, not production activities, are part of this business component.

a. The Section 174 Test

In the opinion of Dr. Froment, one of petitioner's expert witnesses, the Amoco anticoking project was designed to eliminate several uncertainties, in particular whether the pretreatment would: (1) Inhibit, reduce, or increase coke formation; (2) extend run lengths between furnace turnarounds; and/or (3) adversely affect the downstream manufacturing processes or properties of finished olefins products. While the Amoco technology had shown promise in tests in laboratories and pilot plants, petitioner argues that UCC believed that it had not yet been proven and UCC was unsure whether it would work on its commercial-scale ethylene furnaces.

Respondent argues that the Amoco anticoking project fails the section 174 test because petitioner did not show that UCC undertook the project for the purpose of eliminating an uncertainty. Respondent argues that UCC believed that the Amoco technology's capabilities were already well established because Amoco told UCC that its technology had been successfully tested in two commercial plants. Accordingly, respondent believes that UCC was merely testing the Amoco technology to validate that it worked as Amoco claimed. Respondent argues that UCC did not

realize that Amoco's technology was still developmental until just before it abandoned the project.

Petitioner argues that the technology was promising but far from proven. There is some conflicting evidence in the record as to how well established UCC believed Amoco's technology to be at the time it agreed to test the technology.[46] However, it is clear that neither UCC nor Amoco regarded the technology as proven or established to the point where it could be licensed commercially. The fact that Amoco applied the treatment at no cost to UCC supports petitioner's argument that the technology was not fully established. When UCC decided to undertake the Amoco anticoking project, the information available did not establish that Amoco's technology was capable of preventing or reducing coking on UCC's furnaces. See sec. 1.174-2(a)(1), Income Tax Regs.

Section 174 does not require that the technology be in the very beginning stages of development, only that the taxpayer be uncertain as to whether the technology will improve its product or process. The record supports petitioner's argument that UCC was uncertain as to whether the Amoco anticoking technology would work in UCC's facilities. Therefore, we find that at the time of

[46]Dr. Milks testified that he believed that the Amoco technology was experimental and definitely not proven. Jack Marchio, the technology manager for hydrocarbons R&D at the South Charleston technical center, testified that he thought the Amoco technology was established technology.

the test UCC was uncertain as to whether coke formation could be reduced in its commercial facility and, if so, whether Amoco's technology would reduce it.

Respondent also argues that the Amoco anticoking project is not qualified research because it does not satisfy the test of Mayrath v. Commissioner, 41 T.C. at 590. Respondent argues that most of the claimed costs associated with the Amoco anticoking project relate primarily to production activities, not the development of the concept of the Amoco anticoking technology.

We agree with respondent that many of the activities involved in the Amoco anticoking project did not relate to the development of the concept of using the Amoco technology to reduce coke formation but instead constituted production activities, such as the basic operation of furnace 24 and all downstream activities. These production activities relate primarily to the production of ethylene, not the improvement of UCC's production process. Accordingly, they are part of the product business component, not the process business component at issue, and do not affect our analysis. To the extent that petitioner has included production activities as part of the business component, we may apply the shrinking-back rule and apply the qualified research tests to the most significant subset of elements of the process that satisfies the qualified research tests, which we find to be the subset of activities that relate

primarily to the testing of the Amoco technology. See sec. 1.41-4(b)(2), Income Tax Regs.

We find that the following activities relate primarily to the testing of the Amoco technology and are therefore the focus of our inquiry: (1) Reviewing research of prior testing of the Amoco technology; (2) preparing a test plan; (3) designating reference and experimental cracking sets; (4) preparing for the test; (5) applying the pretreatment; (6) collecting test data; (7) analyzing the data; (8) forming of a conclusion; (9) refining the hypothesis; and (10) repeating steps 4 through 8 for the refined hypothesis (collectively, Amoco anticoking research activities). We find that these activities related to the development of the concept of using the Amoco anticoking technology and therefore are not excluded under Mayrath. Accordingly, the Amoco anticoking research activities, as defined above, satisfy the section 174 test.

b. The Technological Information Test

Petitioner argues that the Amoco anticoking project satisfies the technological information test because the information it sought to discover was based on organic chemistry, chemical engineering, and other sciences. We agree that the Amoco anticoking research activities satisfy this test.

c. The Business Component Test

Petitioner argues that the Amoco anticoking project satisfies the business component test because it was designed to improve the performance of its olefins production processes by reducing coke formation. We agree that the Amoco anticoking research activities, as defined in part a., satisfy this test.

d. Process of Experimentation Test

In the opinion of Dr. Froment, the Amoco anticoking project consisted of a process of experimentation in the scientific sense because UCC: (1) Researched and considered a variety of anticoking technologies; (2) developed and implemented a detailed test plan by designating reference versus experimental cracking sets, applying the pretreatment, and recording test data; (3) analyzed the results; (4) refined the process after results from the first test were not satisfactory; (5) retested the product; and (6) drew a conclusion. Petitioner argues that substantially all of the activities involved in the Amoco anticoking project were part of this process of experimentation and that the project was conducted for a qualified purpose--the evaluation of whether the Amoco pretreatment would improve the olefins production process by inhibiting coke formation.

Respondent argues that UCC’s activities did not constitute a process of experimentation because UCC was merely validating Amoco’s claim that the technology worked.

We find that the Amoco anticoking research activities constitute a process of experimentation. UCC did not merely determine whether the Amoco technology inhibited coke formation but instead collected and analyzed data that could be used to compare the technology with alternatives. When the first pretreatment proved to be unsuccessful, UCC considered that the problem might have been the fact that the pretreatment was applied over coke remaining after a hot decoke. UCC refined the process by applying the second pretreatment to the furnace after a cold turnaround. After UCC applied the second pretreatment in April 1995, it continued to collect and analyze data until August 1995, and it used the data analysis to evaluate the technology. While UCC did not continue to refine its hypothesis as to the effectiveness of the Amoco technology and test it for four consecutive furnace cycles as it had planned, satisfaction of the process of experimentation test does not require a taxpayer to continue testing a hypothesis that has no possibility of success. Such a requirement would be contrary to the purpose of section 41. Accordingly, we find that UCC used a process of experimentation to evaluate the Amoco technology and did not merely change its process and decide whether the change satisfied its basic needs.

Petitioner argues that this project was undertaken for a qualified purpose–-to evaluate the efficiency of the Amoco

technology at inhibiting coke formation in order to improve the function, reliability, and performance of the ethylene production process. Successful coke inhibition would have resulted in significantly longer furnace runs, reduced maintenance, longer equipment life, and increased ethylene productivity, yielding significant cost savings and increased profits. We agree that this was a qualified purpose.

Respondent counters that even if the Amoco anticoking project exhibits some characteristics of research, it fails the "substantially all" test. See Norwest Corp. & Subs. v. Commissioner, 110 T.C. at 497. Respondent argues that substantially all of the activities for which petitioner is claiming QREs do not constitute elements of a process of experimentation but instead constitute production activities.

We agree that the ordinary production activities that would have occurred even if UCC was not conducting an experiment do not constitute elements of a process of experimentation. However, as discussed above with regard to the section 174 test, we find that the qualified research tests should be applied solely to the Amoco anticoking research activities. Accordingly, we consider only whether these activities satisfy the process of experimentation test. We find that when we limit the project to only the Amoco anticoking research activities, "substantially

all" of those activities satisfy the process of experimentation test.

Respondent argues that even if the Amoco anticoking project satisfies the qualified research tests, it is excluded from the definition of qualified research because it constitutes funded research, research after commercial production, or data collection and routine testing.

e. Funded Research

Section 41(d)(4)(H) provides that research is not qualified research "to the extent funded by any grant, contract, or otherwise by another person". The evidence shows that Amoco and UCC each paid their own costs during the Amoco anticoking project. While Amoco covered the cost of applying the pretreatment and was contractually obligated to pay for any overtime worked by UCC employees, petitioner did not include any of these costs in its QRE calculations.

Respondent argues that under section 1.41-4A(d)(2), Income Tax Regs., as made applicable by section 1.41-4(c)(9), Income Tax Regs., research is treated as fully funded "If a taxpayer performing research for another person retains no substantial rights in research under the agreement providing for the research". Furthermore, under section 1.41-4A(d)(3), Income Tax Regs., "A taxpayer does not retain substantial rights in the

research if the taxpayer must pay for the right to use the results of the research."

However, petitioner is not seeking credit for research conducted for the benefit of Amoco or that Amoco would purchase from UCC. It would clearly violate Congress's intent in enacting section 41 if a taxpayer could seek a tax credit for research that it did not ultimately pay for. Petitioner is also not seeking credit for the costs that Amoco incurred to develop the technology. Petitioner is seeking credit for research that UCC performed for its own benefit and at its own cost. While UCC did not gain any rights to Amoco's technology by conducting the Amoco anticoking project, UCC retained all rights to its own research. Petitioner produced credible evidence at trial that the information that UCC gained during the Amoco anticoking project was valuable regardless of whether it licensed Amoco's technology or not. Accordingly, we find that the Amoco anticoking research activities do not constitute funded research.

f. Research After Commercial Production

Respondent argues that the Amoco anticoking project is research after commercial production because UCC's olefins process already met its functional and economic requirements. Respondent points out that the Amoco anticoking project did not disrupt UCC's normal production process and resulted in a salable

product. Respondent argues that UCC was simply tweaking its existing process.

Petitioner argues that the Amoco anticoking project was not merely research after commercial production but was a process of experimentation that UCC had to conduct before deciding whether to license Amoco's technology. As discussed above, it is only the Amoco anticoking research activities that we must examine, not UCC's entire olefins process, which we agree already met UCC's basic functional and economic requirements and was used commercially. We conclude that the Amoco technology was not yet ready for commercial use at the time UCC undertook the Amoco anticoking project. The fact that Amoco's technology ultimately failed is a clear indication that it did not meet UCC's needs. Petitioner further argues that the Amoco anticoking project was not a "trial production run" because it was conducted before the potential process improvement, the Amoco technology, was satisfactorily tested and proven. We agree with petitioner that the Amoco anticoking research activities were not merely research after commercial production and are not excluded from the definition of qualified research by section 41(d)(4)(A).

g. Data Collection and Routine Testing

Respondent next argues that the Amoco anticoking project is specifically excluded from the definition of qualified research because it constitutes routine data collection, routine or

ordinary testing, or inspection for quality control. Respondent argues that after the initial results from the first pretreatment suggested failure, the activities occurring during the remaining period were primarily the accumulation of data. Respondent points out that some of the data that UCC collected were routinely collected in its normal operations and was available to UCC regardless of whether a test were being conducted.

Petitioner counters that during the Amoco anticoking project UCC collected some data that it did not normally measure and took other measurements more frequently than it normally took them. Furthermore, petitioner points out that UCC analyzed the collected data, which UCC did not normally do. While UCC did take some measurements during the normal olefins production process, petitioner argues that the purpose of those measurements was to ensure that furnace was operating normally. By contrast, petitioner argues that during the Amoco anticoking project UCC took many more measurements for the purpose of determining whether Amoco's anticoking technology actually reduced the formation of coke and whether the technology could improve UCC's production process. We agree that UCC's activities went beyond routine data collection and that the Amoco anticoking research activities are not excluded from the definition of qualified research by section 41(d)(4)(D).

h. Substantiation Requirement

Respondent finally argues that even if the Amoco anticoking project would otherwise satisfy the qualified research tests, petitioner has not substantiated its claim after the 10th week of testing. While the activities that occurred from the first pretreatment to the cold turnaround in January 1995 were documented in the project report dated February 21, 1995, respondent points out that there is no comparable project report to corroborate UCC's argument that the Amoco anticoking project continued with a second pretreatment in April 1995 and additional testing until the August 1995 cold turnaround. Respondent argues that petitioner was unable to find any data or analysis of data collected after February 21, 1995. Therefore, respondent argues that petitioner has failed to substantiate any activities after the February 21, 1995, project report was written. See sec. 6001; Boyd v. Commissioner; 122 T.C. 305, 320 (2004); Tyson Foods, Inc. & Subs. v. Commissioner, T.C. Memo. 2007-188; Eustace v. Commissioner, T.C. Memo. 2001-66; sec. 1.6001-1, Income Tax Regs.

Petitioner argues that there is sufficient evidence to show that UCC continued to run the test and evaluate data until August 1995. Petitioner offered four witnesses who corroborated that the second test occurred, two of whom confirmed that the test lasted until August 1995. Furthermore, petitioner submitted

documentary evidence that confirms the testimony and shows that some analysis was performed on the data collected from the second test. One of respondent's own expert witnesses, Mr. Halle, concluded that the Amoco anticoking project lasted 8 to 9 months. Accordingly, on the basis of the entire record, we conclude that petitioner sufficiently substantiated its claim that the Amoco anticoking project included a second test that ran from April to August 1995.

On the basis of the foregoing, we hold that the Amoco anticoking research activities were qualified research.

3. The Spuds Project

Petitioner originally claimed that the spuds project was qualified research but now concedes that it does not satisfy the requirements of section 41(d). Dr. Wadia testified that, in his opinion, the spuds project did not constitute research or experimentation in the scientific sense. Dr. Wadia believes that the spuds project was a standard mechanical design change followed by routine plant troubleshooting. Dr. Wadia also believes that the spuds project presented a low level of uncertainty because UCC had been using one-hole spuds at Olefins-2 for 18 years.

Petitioner originally argued that the relevant business component was the olefins production process. As discussed above, under section 41(d)(2)(C) and section 1.41-4(b)(1), Income

Tax Regs., we find that only activities that relate to the improvement of UCC's olefins production process, not production activities, are part of this business component.

a. The Section 174 Test

In the opinion of Dr. Martin, another of petitioner's expert witnesses, the purpose of the spuds project was to eliminate uncertainties concerning improvements that might be achieved in the operation of the Olefins-1 furnaces by replacing the four-hole spuds with one-hole spuds. Dr. Martin's opinion is that it would be impossible to determine the impact of the change on all of the various operating conditions in the furnace by calculation or by testing in a small test facility similar to the test facilities operated by burner vendors. Petitioner originally argued that the specific uncertainties that the spuds project was designed to eliminate were whether the new spud design would: (1) Reduce plugging, carbon monoxide levels, and erratic burner flame patterns; (2) increase furnace fuel efficiency; and/or (3) adversely affect furnace operations or downstream processes. Specifically, UCC was concerned that using the one-hole spuds would increase the level of noise from the furnaces above acceptable levels.

Respondent argues that the spuds project fails the section 174 test because the project was not designed to eliminate any uncertainties. Ms. McClung, one of respondent's expert

witnesses, testified that the one-hole spud design maintained the same design flow area as the four-hole spuds and did not necessitate testing to validate performance. In Ms. McClung's opinion, changing the number of spud holes without changing the total area of the holes would not be expected to significantly affect anything concerning the furnace or burner operation other than to reduce or eliminate the plugging problem. Furthermore, Ms. McClung believes that UCC's experience with one-hole spuds on its Olefins-2 furnaces eliminated any uncertainties that may have otherwise existed. Accordingly, respondent argues that UCC was certain that replacing four-hole spuds with one-hole spuds would result, at a minimum, in the improvement of the plugging problem on the basis of its use of the one-hole spuds at Olefins-2 and common sense.

Petitioner's fact witnesses testified that they hoped that the one-hole spuds would improve the process, but they were not certain. However, the section 174 test requires that an objective uncertainty exist as to the capability or method for developing or improving a product or process or the appropriate design of a product or process. See Mayrath v. Commissioner, 41 T.C. at 590-591. We find that regardless of whether some of UCC's employees were not certain that the one-hole spuds would improve UCC's production process at Olefins-1, UCC had sufficient information available to it, both information gathered from its

own experiences using one-hole spuds and information provided by the John Zink Co., to be certain that the one-hole spuds were capable of improving UCC's production process.

Furthermore, UCC was certain that changing the four-hole spuds to one-hole spuds was the appropriate method for reducing plugging. UCC knew that changing the spuds would be an effective and relatively inexpensive way to solve the problem.

Finally, there was no uncertainty as to the appropriate design of the improvement. The John Zink Co. designed the one-hole spud, and there is no evidence that UCC ever considered adapting the John Zink Co.'s design.

b. The Remaining Tests

Because the spuds project fails the section 174 test, we need not address whether it satisfies the remaining tests.

4. The Sodium Borohydride Project

Petitioner claims that the sodium borohydride project is qualified research. Petitioner identified the olefins production process as the relevant business component. As discussed above, under section 41(d)(2)(C) and section 1.41-4(b)(1), Income Tax Regs., we find that only activities that relate to the improvement of UCC's olefins production process, not production activities, are part of this business component.

a. The First Three Tests

As explained below, we find that the sodium borohydride project fails the process of experimentation test. Accordingly, we need not discuss whether it satisfies the section 174, technological information, or business component test.

b. The Process of Experimentation Test

Petitioner argues that the sodium borohydride project satisfies the process of experimentation test because substantially all of the activities involved constitute a process of experimentation designed to determine whether UCC could effectively use sodium borohydride to remove acetaldehyde to below 100 ppm while the MEA system was out of service. Petitioner argues that the process involved: (1) Considering alternatives, most notably sodium bisulfate; (2) preparing a detailed project memorandum and an FOCR; (3) posing and answering a series of questions about the proposed sodium borohydride injections; (4) determining test dosages and injection rates; (5) injecting the sodium borohydride; (6) sampling the cracked gas stream and crude butadiene product for acetaldehyde; (7) sampling the wastewater for boron; (8) analyzing the results; and (9) evaluating the results and drawing the conclusion that sodium borohydride had successfully removed acetaldehyde to below specification levels. Furthermore, petitioner argues that the process of experimentation was for qualified purposes–-improved

function and performance of Taft's ethylene production process and improved quality of the consumer product.

Respondent argues that the sodium borohydride project did not involve a process of experimentation but was merely a method of reducing the acetaldehyde in UCC's crude butadiene. Respondent argues that UCC was not evaluating alternatives but was simply validating that injecting sodium borohydride could be used to remove acetaldehyde and troubleshooting any problems that came up. Respondent argues that while sodium bisulfate could have been used as an alternative to sodium borohydride, UCC never seriously considered using sodium bisulfate because it knew that sodium borohydride would work better. In respondent's opinion, the occurrence of operating issues or the collection of data does not make a process one of experimentation. Respondent argues that the sodium borohydride project lacked any analysis of the data collected or evaluation of the process change beyond validating that the change satisfied UCC's needs.

We agree with petitioner that the sodium borohydride research activities were designed to resolve uncertainty. Even if the capability of using sodium borohydride to remove acetaldehyde was generally known, UCC was not certain whether (1) sodium borohydride was the appropriate method for removing acetaldehyde from crude butadiene while the MEA system was out of

service given its high cost and unknown efficiency or (2) UCC's design for injecting sodium borohydride was appropriate.

However, to constitute a process of experimentation, the sodium borohydride project research activities must have been designed not only to test whether sodium borohydride satisfied UCC's needs but to evaluate the use of sodium borohydride through a sequential process of experimentation. Such a process would include not only planning the test, implementing the test, and collecting data, but would also include analyzing of the data collected, refining and discarding hypotheses, and progressively developing the process. There is no evidence to support UCC's assertion that it actually analyzed the data it collected beyond determining that sodium borohydride reduced acetaldehyde below 100 ppm. While petitioner argues that UCC was uncertain about the appropriate dosages or injection rates, there is no evidence that UCC experimented with dosages or injection rates or determined the optimal dosage and injection rate. UCC was merely validating that injecting sodium borohydride into the caustic scrubber would reduce acetaldehyde to on-specification levels.

There is also no evidence that the results of the test were sufficiently analyzed so that UCC could compare them with the results of tests of other alternatives. UCC's data collection alone, no matter how extensive, does not constitute a process of experimentation if it is not followed by meaningful analysis.

While Dr. Manyik prepared an R&D report for the sodium borohydride project that UCC considered to be the functional equivalent of a project report, Dr. Manyik prepared the R&D report before the test of sodium borohydride occurred. Therefore, it could not have included any analyses of the project that were not available before the project began. The fact that UCC found Dr. Manyik's R&D report and other prerun reports sufficient to document the sodium borohydride project indicates that UCC did not find it necessary to analyze the results of the project and was not interested in developing or refining its process. Accordingly, we find that the sodium borohydride research activities fail the process of experimentation test and were not qualified research. We need not address respondent's remaining arguments relating to this project.

5. The UOP GA-155 Project

Petitioner argues that the UOP GA-155 project is qualified research and that the relevant business component is the olefins production process. As discussed above, under section 41(d)(2)(C) and section 1.41-4(b)(1), Income Tax Regs., we find that only activities that relate to the improvement of UCC's olefins production process, not production activities, are part of this business component.

a. The Section 174 Test

Petitioner argues that the UOP GA-155 project satisfies the section 174 test because it was designed to eliminate uncertainties as to: (1) Whether UOP GA-155 would reduce butadiene polymer fouling in the C_3 column and reboilers; (2) the proper dosage of UOP GA-155 to both reduce C_3 column fouling and stabilize the dripolene; and/or (3) whether UOP GA-155 would adversely affect Taft's downstream processes and commercial products. Petitioner argues that these uncertainties could not have been resolved without a plant test because laboratory tests would not translate well to the plant.

Respondent argues that the UOP GA-155 project fails the section 174 test because any uncertainties with respect to injecting UOP GA-155 had been resolved before the project began. Respondent believes that the only question that remained was how much UOP GA-155 to use, and UCC intended to resolve this issue by obtaining advice from UOP, not through its own testing. Respondent argues that there were no issues with respect to the capability or method for developing or improving the process or the appropriate design of the process but that UCC was merely verifying UOP's claims that UOP GA-155 would reducing fouling. If there were any uncertainties with respect to the UOP GA-155 project, respondent argues that they would have been reflected in the FOCR.

While UCC's employees testified that they were uncertain whether UOP GA-155 would reduce fouling, we find that the information available to UCC established that UOP GA-155 would be effective. The evidence shows that UOP, not UCC, performed the research to determine UOP GA-155's effectiveness. The fact that UCC desired to confirm UOP's assertions with its own testing does not create an uncertainty within the meaning of section 174. The section 174 test is an objective test, and a taxpayer may not turn its back on the available information in order to create uncertainty.

Furthermore, there is no evidence that UCC was uncertain as to the appropriate method for reducing fouling. UCC had significant experience using inhibitors before beginning the UOP GA-155 project and there is no evidence that UCC had any doubt that injecting an inhibitor into the C_3 column was the appropriate method to reduce fouling in the C_3 column.

Finally, UCC had sufficient information available to it to eliminate any uncertainties as to the appropriate design of using UOP GA-155 to reduce fouling in the C_3 column. It was UOP that developed UOP GA-155, studied UCC's process, and recommended the design that UCC should use to inject UOP GA-155. There is no evidence that UCC intended to use the UOP GA-155 project to discover information to improve upon or change the design suggested by UOP.

b. The Remaining Tests

Because the UOP GA-155 project fails the section 174 test, we need not address whether it satisfies the remaining qualified research tests.

6. The UCAT-J Project

Petitioner claims that the UCAT-J project is qualified research and that the relevant business component is the PE production process. Respondent argues that each of the individual UCAT-J runs constitutes a separate project. We find that the UCAT-J runs were separate tests in the same project to develop the use of UCAT-J in UCC's PE production process and should be treated as a single business component. However, as discussed above, under section 41(d)(2)(C) and section 1.41-4(b)(1), Income Tax Regs., we find that only activities that relate to the improvement of UCC's PE production process, not production activities, are part of this business component.

a. The Section 174 Test

In the opinion of Dr. Brockmeier, one of petitioner's expert witnesses, the UCAT-J project was designed to discover information that would eliminate several uncertainties relating to whether UCC could use UCAT-J to produce PE base resins in Star's UNIPOL reactors with reactor operability and continuity and product properties equivalent to or better than those that could be achieved using M-1. For example, Dr. Brockmeier

believes that UCC was uncertain whether using UCAT-J as the catalyst would increase the amount of static in the reactor and cause operability problems. Static was a greater problem with UCAT-J than with M-1 because of the dielectric properties of the UCAT-J system. In Dr. Brockmeier's opinion, UCC could not discover how to solve this problem at the pilot plants or smaller commercial reactors because static was less of a problem in smaller reactors. Petitioner argues that other examples of operability issues related to UCAT-J were UCC's ability to: (1) Control bulk density when producing butene film resins; (2) reduce resin stickiness without reducing catalyst productivity; and (3) prevent TEAl starvation. Petitioner argues that these issues created uncertainties regarding UCC's capability of using UCAT-J to produce base resin and/or uncertainties regarding the design for using UCAT-J to develop or improve its UNIPOL process technology used at Star. Petitioner argues that the UCAT-J project was intended to discover information that would eliminate these uncertainties.

In the opinion of Dr. Brockmeier, the "rule of three" followed at Star was reasonable and one or even two problem-free experiments does not provide a manufacturer with sufficient assurance that the technology can be used without R&D supervision and involvement. Dr. Brockmeier also believes that the duration of the UCAT-J runs was scientifically reasonable and that UCC was

continuing to discover information about UCAT-J's operability after the reactor was lined out and reached a steady state. In Dr. Brockmeier's opinion, the UCAT-J runs were not merely trial production runs because UCC had not yet eliminated the uncertainties associated with the new technology.

Respondent's analysis of the UCAT-J project relies on the report of one of his expert witnesses, Dr. Allen. Respondent argues that the UCAT-J project fails the section 174 test because: (1) UCC was certain that it could produce aim-grade base resin using UCAT-J; and (2) the UCAT-J project was conducted for the purpose of producing products for sale to customers, not for the purpose of discovering information.

i. Uncertainty

Respondent argues that the UCAT-J project fails the section 174 test because UCC was certain that it could produce aim-grade base resin using UCAT-J. Respondent argues that UCC gained this certainty because it had successfully used UCAT-J on the UNIPOL pilot plant as well as at Star and Seadrift. Respondent believes his argument is supported by the fact that UCC had enough confidence to begin designing LP-6, which was designed to use UCAT-J, and to tout the benefits of UCAT-J to UNIPOL licensees before it began the UCAT-J project.

Respondent argues that the Court should consider petitioner's arguments and testimonial evidence against the

documentary evidence made contemporaneously with the runs. In support of his argument, respondent cites United States v. United States Gypsum Co., 333 U.S. 364, 395-396 (1948), where the Supreme Court stated:

> Both on direct and cross-examination counsel were permitted to phrase their questions in extremely leading form, so that the import of the witnesses' testimony was conflicting. * * * Where such testimony is in conflict with contemporaneous documents we can give it little weight, particularly when the crucial issues involve mixed questions of law and fact. * * *

Respondent points to documents dated before the UCAT-J project began indicating that UCC had produced aim-grade resin on its smaller reactors without significant operability or continuity problems and that UCAT-J performed better than M-1 on the pilot plant. Respondent also argues that the pre-run documentation does not identify the uncertainties that petitioner claims existed before the runs.

We agree with respondent that some of the documentary evidence indicates that UCC was confident that at some point it would be able to produce base resin using UCAT-J on a commercial scale and sell UCAT-J to licensees. Furthermore, we find that UCC generally found UCAT-J to work as well as or better than M-1 in its pilot plants. However, this not end our inquiry. Even if UCC was certain that it was capable of using UCAT-J commercially, the section 174 test may also be satisfied "if the information available to the taxpayer does not establish the * * *

appropriate design of the product." Sec. 1.174-2(a)(1), Income Tax Regs. The documentary evidence indicates that UCC was confident that it would eventually be able to use UCAT-J with satisfactory operability and continuity, but it does not indicate that UCC knew how to design its process so that (1) using UCAT-J would be an improvement over using M-1 in its full-size commercial reactors and (2) UCC could fully use UCAT-J's superior qualities. Many of the documents in evidence list the objectives and the risks involved in the runs, and petitioner confirmed through testimony that each of the runs was conducted for the purpose of discovering information that would help eliminate uncertainties as to how UCC could improve its PE production process using UCAT-J. Therefore, we find that the testimony does not conflict with the documentary evidence.

Furthermore, we find that at the beginning of 1994 UCC did not have enough information available to establish how it should design its process so that using UCAT-J would be an improvement over using M-1 on a full-scale commercial reactor. UCC may have been satisfied with the design of its process using UCAT-J in the pilot plant and the smaller reactor at Seadrift, but UCC could not use the same design on Star's reactor because Star's larger size caused problems that did not occur at the smaller plants such as static and sheeting. UCC was still experiencing significant operability and continuity problems at Star that

negated many of the benefits of using UCAT-J. The purpose of testing a process on a pilot plant is to eliminate any uncertainties that can be eliminated at the pilot plant level before moving the experiment to a commercial-scale reactor, but any uncertainties that arise only on larger reactors cannot be eliminated without testing on a commercial-scale reactor. We agree with petitioner that because of the differences between a commercial-scale reactor and a pilot plant reactor there were additional uncertainties relating to the design of the process that could not be eliminated through testing on smaller reactors. Petitioner's argument that testing on smaller reactors would not eliminate all uncertainties regarding the design of a commercial-scale PE production process using UCAT-J is further supported by the fact that UCC decided to install two different sets of catalyst feeders on its LP-6 plant so that M-1 could be used at the plant if UCC was unable to commercialize UCAT-J by the time the plant was completed.

ii. Discovering Information

Respondent argues that even if there were uncertainties as to the design of UCC's process, the UCAT-J runs were not conducted for the purpose of eliminating those uncertainties. In the opinion of Dr. Allen, all of the runs of the UCAT-J project were conducted for commercial reasons. Respondent points out that: (1) UCC sold most of the resin it produced during the

UCAT-J runs; (2) an objective for most of the runs was to produce resin for customer qualification; and (3) many of the runs lasted longer than the time necessary to achieve a steady state in the reactor.

We agree that some of UCC's objectives were commercial as we would expect, considering that UCC's ultimate goal was to commercialize the use of UCAT-J and the UCAT-J project included both process and product business components. However, we find that the record supports petitioner's argument that the primary goal of UCC's activities that related to the process business component was to discover information to eliminate uncertainties as to the appropriate design of UCC's PE production process when UCAT-J was used as the catalyst. UCC's production activities, by contrast, are part of the product business component of the UCAT-J project and are outside the scope of our inquiry.

Respondent also points out that UCC wanted its plant operators to gain experience making products with UCAT-J in anticipation of the completion of LP-6. While this may have been an additional objective of the UCAT-J project, we do not believe that it was the primary objective.

Respondent next argues that the even if the UCAT-J project otherwise satisfies the section 174 test, it fails the test of Mayrath v. Commissioner, 41 T.C. 582 (1964). Respondent argues that most of the claimed costs associated with the UCAT-J project

related to production activities, not activities related to the development of the concept of the project.

We agree that the activities that related primarily to the production of PE base resin were not related to the development of the concept of using UCAT-J and may not be treated as expenses under section 174. See Mayrath v. Commissioner, supra at 590. However, we conclude that these production activities are part of the product business component, not the process business component at issue. To the extent that petitioner has included production activities as part of the business component, we may apply the shrinking-back rule and apply the qualified research tests to the most significant subset of elements of the process that satisfies the qualified research tests, which we find to be the subset of activities that relate primarily to the development of the production process using UCAT-J. See sec. 1.41-4(b)(2), Income Tax Regs.

The activities that relate primarily to the development of the production process using UCAT-J are part of the process business component, and we find that they satisfy the Mayrath test. These activities include: (1) Preparing run documentation, including identifying objectives and risks of each run; (2) monitoring reactor performance; (3) responding to unexpected operating problems; (4) conducting experiments during the runs; (5) collecting resin and catalyst samples; (6)

reporting run performance both during and following each run; (7) analyzing the results of each run; (8) identifying ways to improve subsequent runs; and (9) implementing improvements in subsequent runs (collectively, UCAT-J research activities).

Respondent finally argues that the UCAT-J project fails the section 174 test because the duration of many of the runs far exceeded the duration necessary to discover information to resolve uncertainties. We disagree, and we find that activities that relate primarily to the development of the process, as opposed to the production of base resin, may satisfy the section 174 test regardless of when they occurred as long as they were performed for the purpose of discovering information to eliminate the uncertainties discussed above. We find that the UCAT-J research activities were performed for this purpose.

b. The Technological Information Test

Petitioner argues that the UCAT-J project satisfies the technological information test because it was designed to discover information based upon numerous principles of chemistry and engineering including: (1) Catalytic chemistry; (2) polymerization; (3) heat and mass transfer; (4) reaction kinetics; (5) statistics; (6) fluid dynamics and solubility; (7) chemical engineering; and (8) process engineering. We agree that the UCAT-J research activities satisfy this test.

c. The Business Component Test

Petitioner argues that the UCAT-J project satisfies the business component test because the project was intended to discover information that would be useful for improving UCC's PE production process. We agree that the UCAT-J research activities satisfy this test.

d. The Process of Experimentation Test

Petitioner claims that substantially all of the activities involved in the UCAT-J project constitute elements of a process of experimentation for a qualified purpose. In Dr. Brockmeier's opinion, the UCAT-J project involved a constant process of evaluation and experimentation including: (1) Preparing run documentation that identified the objectives and risks of each run; (2) monitoring reactor performance; (3) responding to unexpected operating problems; (4) conducting experiments during the runs; (5) collecting resin and catalyst samples; (6) reporting run performance both during and following each run; (7) analyzing the results of the runs; and (8) developing ways to improve the process during subsequent runs.

Dr. Brockmeier believes that the run team's activities--meeting regularly to discuss objectives, identifying obstacles, proposing alternative remedies, and evaluating reaction system responses to the experimental remedies–-indicate that the project was conducted using a process of experimentation in the

scientific sense. Dr. Brockmeier also noted various experiments that UCC conducted during the UCAT-J project, including: (1) Adjusting operating ratios and chemicals; (2) adjusting ethylene partial pressure; (3) modifying catalyst properties; (4) introducing new reactor control technologies; and (5) giving the reactor TEAl shots. Dr. Brockmeier concluded in his report: "Viewed in its entirety, the UCAT-J Project is a textbook example of the R&D-driven process of experimentation that is required in order to implement a catalyst change in a large-scale PE production process."

Petitioner also claims that the UCAT-J project was performed for a qualified purpose––to improve the function and performance of the PE production process and to improve the quality of the consumer product. UCAT-J, if successfully commercialized, offered many process-related advantages over M-1 because it was more active than M-1 and therefore could produce more base resin. Furthermore, if UCAT-J worked properly, it would improve PE product properties.

Respondent argues that the UCAT-J project fails the process of experimentation test because respondent believes that UCC had already eliminated all uncertainties related to the use of UCAT-J before the credit years and accordingly no experimentation was necessary. As discussed above with respect to the section 174 test, we find that UCC had not eliminated all uncertainties

relating to the design of its PE production process using UCAT-J on a commercial scale before completing the project.

Respondent also argues that petitioner failed to produce any formal project reports that analyzed the results of the UCAT-J project. While such formal project reports would indicate a process of experimentation, we are satisfied that UCC sufficiently analyzed the results through discussion and informal documentation. Petitioner presented credible testimony that process R&D collected data during the UCAT-J runs, process R&D representatives and members of the run team analyzed and discussed the results, and UCC used these analyses to further refine the PE production process using UCAT-J. The fact that UCC was able to compare its production process using UCAT-J with its production process using M-1 in terms of reactor operability and continuity issues indicates that UCC could use the same process to compare UCAT-J with other catalysts.

We find that the UCAT-J research activities constitute a process of experimentation. Unlike the sodium borohydride project, the UCAT-J project was not a simple change to a process followed by verification that the change would work. UCC conducted a series of trials using UCAT-J and analyzed the results of each trial to develop and improve its process. UCC was testing hypotheses and forming new hypotheses based on each succeeding run in order to solve some of the chemical and

physical problems it had experienced using UCAT-J. Throughout the UCAT-J project UCC was comparing UCAT-J's performance to M-1's performance on a variety of criteria related to reactor operability, reactor continuity, and product properties.

While many of the activities that were conducted during the UCAT-J project as a whole did not constitute a process of experimentation but were ordinary production activities, as discussed above we find it appropriate to separate the production activities and the research activities into separate business components for the nonexperimental product and the experimental process, respectively. Therefore, the occurrence of nonexperimental production activities does not cause the UCAT-J research activities to fail the "substantially all" portion of the process of experimentation test. Furthermore, we find that the improvement of UCC's PE production process is a qualified purpose under section 41(d)(3). Accordingly, we find that the UCAT-J research activities satisfy the process of experimentation test.

e. Research After Commercial Production

Respondent next argues that the UCAT-J project is excluded from the definition of qualified research because it constituted research after commercial production, specifically trial production runs, troubleshooting, or debugging. Respondent

argues that the UCAT-J runs occurred after the preproduction planning and trial production runs had occurred.

We disagree that the UCAT-J research activities constituted research after commercial production. While the aim-grade base resin that UCC produced satisfied UCC's basic functional and economic requirements, the business component at issue is the process business component, not the product business component. UCC's production process using UCAT-J did not satisfy its basic functional and economic requirements during the credit years. UCC was not yet licensing the use of UCAT-J and was not using UCAT-J as its primary catalyst for production. UCC was still experimenting to eliminate significant problems that counteracted the benefits of using UCAT-J instead of M-1. Accordingly, we find that the UCAT-J research activities are not excluded from the definition of qualified research under section 41(d)(4)(A).

f. Substantiation Requirement

Respondent finally argues that petitioner has not produced sufficient documentary evidence to corroborate the testimony of its fact witnesses in support of its argument that the UCAT-J project was qualified research. See sec. 6001; sec. 1.6001-1, Income Tax Regs.; see also Boyd v. Commissioner, 122 T.C. at 320; Tyson Foods, Inc. & Subs. v. Commissioner, T.C. Memo. 2007-188; Eustace v. Commissioner, T.C. Memo. 2001-66.

Petitioner argues that there is sufficient evidence to show that the UCAT-J project occurred and satisfies the qualified research tests. Petitioner produced three fact witnesses to discuss the UCAT-J project and argues that their testimony is corroborated by sufficient documentary evidence that provides the objectives, risks, and results of the runs.

Considering the record in its entirety, we find that petitioner substantiated its claim that the UCAT-J research activities satisfy the qualified research tests. Accordingly, these research activities, but not ordinary production activities, constitute qualified research.

III. Base Period Activities

We next address whether petitioner included all activities similar to the activities that we find constitute qualified research in making its revised base period computations. A taxpayer must determine its QREs to be taken into account in computing its fixed-base percentage "on a basis consistent with" its determination of QREs for the credit year. Sec. 41(c)(4).[47] Accordingly, the taxpayer must include the same types of activities as qualified research and include the same types of costs as QREs for the credit years and the base period. The legislative history explains:

> if a taxpayer includes (or excludes) certain expenditures in determining its qualified research

[47]See supra note 41.

> expenses for the current year, it must provide the same treatment for all such expenditures incurred during any year taken into account in computing the taxpayer's fixed-base percentage * * *. [H. Rept. 101-247, at 1202-1203 (1989).]

A. Whether Petitioner Must Include Activities Conducted By the Entire Consolidated Group

In its order dated January 17, 2007, the Court ordered that for purposes of conforming the base period computations to the methodology petitioner employed to compute the claimed credits, only evidence of the revised base period computations for the legal entity for which additional credits are claimed would be necessary. Because petitioner claimed additional credits only for activities conducted by UCC, the base period trial was limited to UCC's base period computations.

In response to petitioner's motion for partial summary judgement dated September 15, 2006, respondent argued[48] that petitioner was required to calculate its QREs for the base period for the entire controlled group on a consistent basis with its QRE calculation for the claim projects. This would require petitioner to include in its revised research credit computations the QREs incurred not only by UCC, but also the other members of petitioner's controlled group. Respondent pointed to section 41(f)(1), which provides:

[48]Respondent did not repeat these arguments on brief and acknowledges that the Court has already decided this issue. However, respondent reserves his arguments with respect to this issue. Accordingly, we address his arguments here.

(1) Aggregation of expenditures.--

(A) Controlled group of corporations.--In determining the amount of the credit under this section--

(i) all members of the same controlled group of corporations shall be treated as a single taxpayer, and

(ii) the credit (if any) allowable by this section to each such member shall be its proportionate shares of the qualified research expenses and basic research payments giving rise to the credit.

However, we decided that the consistency rule applies to the determination of QREs for each member of the controlled group while the aggregation rule of section 41(f)(1) refers to the determination of the overall credit. The rule for aggregation of expenditures exists "To ensure that the new credit will be allowed only for actual increases in research wage expenditures". S. Rept. 97-144, supra at 83, 1981-2 C.B. at 442. Congress intended for these rules to prevent artificial increases in research expenditures by shifting expenditures among commonly controlled or otherwise related persons. Id. The rules for aggregation were already in place when the consistency rule was enacted as part of the Omnibus Budget Reconciliation Act of 1989, Pub. L. 101-239, sec. 7110(b)(1), 103 Stat. 2323, yet the legislative history does not provide any guidance as to whether the consistency rule applies at the entity level or the consolidated group level. See H. Rept. 101-247, supra at 1202-1203; H. Conf. Rept. 101-386, at 542 (1989). Section 41(c)(4)(B) refers to the "taxpayer", not the controlled group, and there is no indication in

the statute or the legislative history that all members of a consolidated group must calculate their QREs in the same way.

Section 41(c)(4) undercuts the logic of the argument that the consistency rule is to be applied to the controlled group as a whole. Section 41(c)(4)(B) gives the Secretary authority to issue regulations to prevent "distortions" caused by a "change in accounting methods used by such taxpayer". Taxpayers that are part of a commonly controlled group may have different methods of accounting. Because the statute refers only to a single accounting method, it makes no sense to conclude that the consistency rule applies to the controlled group as a whole. Respondent's attempt to read the consistency rule in the light of section 41(f) creates an anomaly.

Respondent argued that petitioner's interpretation of the consistency rule contradicts "unambiguous congressional intent." Respondent asked us to consider the following example:

> A and B are members of a controlled group of corporations. During the base years, A but not B incurred a certain type of QRE. In the credit year, the AB controlled group shifts this type of QRE to B in order to avoid including this item of A's base period QRE in the group credit computation under the consistency requirement.

Respondent argued that petitioner's interpretation of the consistency rule would permit the result in the example. In support of his position, respondent cited the legislative purpose for the aggregation rules: "to prevent artificial increases in

research wage expenditures by shifting expenditures among commonly controlled or otherwise related persons." See S. Rept. 97-144, supra at 83, 1981-2 C.B. at 442. However, the regulations already address respondent's concern. Section 41(f) and the legislative history direct the Secretary to issue regulations to ensure that artificial shifting of research expenditures will not occur. Section 1.41-6(i), Income Tax Regs., addresses the concern of shifting artificial expenditures among members of a controlled group by providing that because all members of a group under common control are treated as a single taxpayer for purposes of determining the research credit, transfers between members of the group are generally disregarded.[49]

There is no support in the statute or the legislative history for the application of the consistency rule at the controlled group level. Accordingly, because petitioner is now seeking additional research credits for activities conducted only by UCC, petitioner properly included base period QREs for only UCC in its fixed-base percentage.

B. Acquisitions and Dispositions

Section 41(f)(3) provides for adjustments to QREs in the event of an acquisition or disposition by the taxpayer. If the taxpayer acquires a major portion of a trade or business, then the taxpayer must increase the amount of the QREs it incurred before the

[49]During the credit years this regulation was found under sec. 1.41-8(e), Income Tax Regs.

acquisition by the amount of QREs incurred by the acquired trade or business during that time. Sec. 41(f)(3)(A). Likewise, in the case of a disposition of a major portion of its trade or business, the taxpayer must decrease the amount of the QREs it incurred before the disposition by the amount of QREs attributable to the trade or business sold. Sec. 41(f)(3)(B).

Section 41(d)(4)(F) excludes from the definition of "qualified research" any research conducted outside the United States, the Commonwealth of Puerto Rico, or any possession the United States. Accordingly, we need not consider any acquisitions or dispositions of businesses that conducted research solely outside the United States during the base period.

UCC's C&P business segment was UCC's only domestic business segment operating during the base period that remained a part of the UCC legal entity during the credit years. Accordingly, we need not consider any of the other business segments that were part of UCC during the base period.[50] We find, and respondent does not dispute, that petitioner has properly accounted for the acquisitions and dispositions that occurred during the relevant periods.

[50]UCC disposed of its consumer products, carbon products, and industrial gases segments before January 1, 1994.

C. Polypropylene Runs

Dr. Wadia contends that the 138 identified polypropylene runs that occurred at Seadrift's P-1 unit satisfy the qualified research criteria. Ms. Toivonen costed the polypropylene runs at $29.5 million. However, petitioner did not include these runs in its base period calculations because petitioner claims that UCC conducted these runs as an independent contractor for SPC and SPC ultimately bore the cost of these runs.

Respondent argues that petitioner should have included the polypropylene runs in its base period calculations because UCC initially bore the costs of the runs, petitioner failed to substantiate that UCC was compensated by SPC, SPC did not maintain separate books and records apart from UCC's books and records, and UCC was required to bear its own costs of conducting R&D under the CUA.

Under the operating agreement between UCC and SPC, SPC agreed to reimburse UCC for any operating expenses it incurred. Petitioner presented testimony at trial that SPC did in fact reimburse UCC for these expenses, and we find the testimony to be credible. Furthermore, while UCC provided accounting services for SPC, petitioner provided credible evidence that UCC kept its records separate from those of SPC.

While we agree that the CUA provides that UCC would bear the costs of R&D it conducted as part of the Cooperative Undertaking,

the polypropylene runs were conducted by SPC, not the Cooperative Undertaking. The polypropylene runs all involved plant-based experimentation, and the Cooperative Undertaking was not involved in any experimentation that occurred during the production process. While the agreements between UCC and Shell relating to SPC provided that any intellectual property discovered or developed by UCC in the course of performing its duties under those agreements would be governed by the CUA, not the SPC agreements, we find that the costs of the polypropylene runs were costs treated as the costs of polypropylene production, not the development of intellectual property, and they would not have been governed by the CUA. Accordingly, the CUA provisions are irrelevant.[51] We see no other reason why SPC should not be respected as a tax partnership, and we accordingly find that petitioner was correct to exclude the polypropylene runs from its base period computations.

D. Whether Petitioner Included All Activities Similar to the Claim Projects on Its List of Identified Runs

Respondent argues that the methodology that petitioner used to identify plant-based research for the claim projects is completely different and fundamentally inconsistent with its methodology for identifying plant-based research that occurred during the base period. We address each of respondent's arguments in turn.

[51]Respondent does not argue that petitioner failed to include additional QREs not identified by Ms. Toivonen that UCC incurred as part of the Cooperative Undertaking. It appears that UCC treated these costs as QREs on its original return.

1. Petitioner's Sources of Information

a. Whether Petitioner Was Required To Use FOCRs To Identify Base Period Activities

Respondent points out that the claim projects were largely documented by FOCRs, but UCC destroyed its FOCRs from the base period before performing its revised base period calculations. Accordingly, petitioner was unable to review all of the FOCRs produced during the base period to see whether they identified additional qualified research activities. Respondent argues that because Dr. Wadia could not review the FOCRs from the base period, petitioner cannot prove that it identified all of the base period activities that were similar to the claim projects. As an example, respondent argues that Dr. Wadia "missed" the Nalco inhibitor antifouling test (run 816), which petitioner later conceded and costed at $7 million. Respondent argues that this process change would have been documented by an FOCR, so Dr. Wadia might not have missed this project had the FOCRs from the base period been available. Respondent argues that FOCRs were the key document indicating manufacturing process changes during both the base period and the credit years. Accordingly, respondent argues that petitioner needed to analyze and produce its FOCRs from the base period in order to meet the consistency requirement and capture all base period activities similar to the claim projects.

Neither section 41(c)(4) nor section 1.41-4(d), Income Tax Regs., imposes any requirement that a taxpayer use the same types

of documents to identify qualified research in the base period as it used to identify qualified research in the claim year if the taxpayer can otherwise show that it has satisfied the consistency requirement. While it is true that Dr. Wadia did not include the Nalco inhibitor antifouling test in his original list of identified runs, we do not view this as evidence that Dr. Wadia "missed" any projects because he did not review FOCRs from the base period. We find that the Nalco inhibitor antifouling test fails the process of experimentation test. UCC was not experimenting with the Nalco inhibitor or conducting research to better understand inhibitors; it was merely testing Nalco's product to see whether it worked as promised. While UCC monitored the reboiler after injecting the Nalco inhibitor, as it did with the UOP GA-155 project, there is no evidence that UCC analyzed the results of the test or intended to refine its hypothesis and conduct additional tests. Such verification, without more, does not constitute a process of experimentation. Accordingly, Dr. Wadia's exclusion of the Nalco inhibitor antifouling test from his list of identified runs does not cause us to doubt his reliability.

Furthermore, while petitioner did rely heavily on FOCRs to establish that the claim projects constitute qualified research, we do not find that FOCRs are as important to identifying qualified research as respondent advocates. FOCRs were used for any process change, regardless of whether the change involved experimentation.

Accordingly, even if all of the FOCRs from the base period were available to Dr. Wadia, we do not believe that this would significantly change Dr. Wadia's conclusions.

Respondent also argues that petitioner chose an ad hoc methodology to identify base period activities and relied on documents that were highly variable in completeness and usefulness. Respondent argues that the absence of any summary documents, such as lists of new products introduced during the base period or R&D budgets, makes it impossible to confirm that Dr. Wadia captured all of the qualified research activities that occurred during the base period. Furthermore, because the documents did not always provide conclusive evidence of the duration or production quantities of the identified runs, Dr. Wadia relied upon estimates and assumptions for a large number of runs. Respondent argues that estimates are legally impermissible.

Section 1.41-4(d), Income Tax Regs., does not require that a taxpayer substantiate its research credit claim with any particular types of documents but requires that the taxpayer "retain records in sufficiently usable form and detail to substantiate that the expenditures claimed are eligible for the credit." We find that the documents that petitioner produced were sufficient to substantiate its claim that the MATRIC team identified all of the scientific research projects that occurred during the base period and were sufficiently detailed to allow the MATRIC team to make

reasonable determinations as to the duration and production quantities of the identified runs.

b. Whether Petitioner Was Required To Consider Alternative Sources

Respondent argues that petitioner should have examined alternative sources to correct defects in its methodology. As an example, because two of the claim projects (the UOP GA-155 and sodium borohydride projects) involved the injection of additives into the olefins production process, respondent argues that petitioner should have sought documents from third parties from whom UCC purchased additives during the base period to see whether they would show whether UCC experimented with different additives during the base period. Respondent argues that the documents produced by the John Zink Co. show that UCC conducted additional plant testing during the base period that was not addressed by Dr. Wadia's report.

Petitioner argues that respondent was unable to obtain any significant documents from third-parties from whom UCC purchased additives during the base period, so any attempt that petitioner would have made to obtain the same documents would have been fruitless. Furthermore, petitioner argues that the third-party documents that are available, those produced by the John Zink Co., did not identify any experimental activities.

We agree that section 41 does not require petitioner to seek documents from third-party sources to determine whether they

contain evidence of experimentation. Furthermore, we find that the documents from third-party sources that were available, those from the John Zink Co., do not indicate that additional research occurred during the base period that petitioner failed to consider. Those documents show that UCC tested the products it purchased, but not that it experimented with them. Considering that we do not find the UOP GA-155 project or the sodium borohydride project to be qualified research, we find it unlikely that documents from UCC's additive vendors or other third parties would be useful in identifying additional qualified research activities conducted during the base period.

2. Whether Petitioner Should Include Additional Activities in Its Base Period Calculation

Respondent argues that petitioner failed to capture all of the qualified research activities that occurred during the base period, specifically: (1) The NOx project, (2) testing on products that UCC purchased from the John Zink Co., (3) testing of the Star pelleting line, and (4) UCC's analysis of naphtha on its list of identified runs. According to respondent, petitioner's failure to include these projects or tests in its base period calculations is evidence that petitioner's identification of qualified research activities was incomplete. Respondent also argues that Dr. Wadia improperly omitted portions of the identified runs.

a. NOx

The NOx project does contain some elements of qualified research to the extent that UCC was attempting to discover information that would allow it to determine whether it was thawing its cold boxes frequently enough to reduce the safety hazard caused by NOx accumulation. However, we find that the NOx project does not satisfy the process of experimentation test because UCC was not conducting an experiment in the scientific sense but was merely performing maintenance on its cold boxes, collecting data, and using the collected data to set operating guidelines.

b. John Zink Co. Products

We also find that UCC did not conduct any qualified research activities related to purchases from the John Zink Co. As with the spuds project, any testing that UCC performed on products purchased from the John Zink Co. was merely quality control testing to ensure that the products worked as promised.

c. Star Pelleting Line

Similarly, while UCC most likely tested the pelleting line it installed at Star in 1986, there is no indication that UCC performed any experimentation associated with the new pelleting line, much less qualified research. Any tests that UCC performed were most likely quality control tests to ensure that the pelleting line did in fact work.

d. Naphtha Analysis

We find that UCC's analysis of naphtha in 1987 was routine data collection or routine or ordinary inspection. There is no indication that UCC performed any experiments when it was determining the composition of the naphtha it purchased.

e. Dr. Wadia's Limitation of Duration

Respondent also argues that even if Dr. Wadia included all of the projects that constitute qualified research on his list of identified runs, Dr. Wadia's interpretation of the definition of "qualified research" was narrower than the definition petitioner used during the claim years. Respondent argues that petitioner treated the entire duration of all of the claim projects as qualified research regardless of whether only part of a run was experimental, while Dr. Wadia limited the run durations to the experimental portions of the identified runs.

For some of the identified runs, Dr. Wadia defined qualified research as including only the portion of a run that he believed was experimental, not the entire run. Accordingly, Dr. Wadia treated the duration of many identified runs as including only the portion of the run where experimentation occurred. For example, if a run was conducted for the purpose of determining whether it would produce a product of acceptable quality, Dr. Wadia would treat the duration of the run as lasting only until the point at which that

determination was made unless the researchers continued to experiment after the unit reached a steady state.

In the MEK production test (run 175), UCC collected data for the first 914 hours of the run, but Dr. Wadia included only the first 336 hours in the duration of run 175. Similarly, for the first vinyl acetate catalyst protection test (runs 47), Dr. Wadia treated the run as lasting only 12 hours even though the resin was in place for 2,400 hours and one of the goals of the test was to test the strength of the resin over a period of 2,400 hours. Dr. Wadia used partial durations for many other runs as well.

Respondent argues that this approach is inconsistent with petitioner's treatment of the UCAT-J runs because petitioner did not limit the duration of those runs to the time it took the reactor to reach a steady state even if no experimentation occurred after that point. Respondent argues that Dr. Wadia's approach is also inconsistent with the UOP GA-155 project, where UCC collected data for only 90 days but treated the project as lasting 6 months. Respondent also argues that the duration of the Amoco anticoking project would have been much shorter if petitioner limited the duration to the time it should have taken UCC to realize that the Amoco technology was not working. Respondent argues that petitioner did not attempt to divide any of the other claim projects into their "experimental" and "non-experimental" parts.

Even assuming respondent is correct, we find that our limitation of the claim projects to only the activities that relate to the experimental process business component is at least as narrow as Dr. Wadia's approach. As discussed with respect to the claim projects, under section 41(d)(2)(C), where research is conducted to improve a taxpayer's production process, activities that relate to the product being produced are part of a separate nonexperimental product business component. Production activities that do not involve experimentation are properly excluded from the definition of qualified research. Therefore, petitioner's reliance on Dr. Wadia's definition of which activities constitute qualified research does not run afoul of section 41(c)(4). Accordingly, we find that there are no additional activities that are similar to the claim year projects that satisfy section 41(d).

3. Reliability of Dr. Wadia's Methodology

Respondent argues that even if the Court does not find that petitioner omitted any particular projects from its list of identified runs, the Court cannot rely on Dr. Wadia's testimony to prove that it identified all of the qualified research activities that occurred during the base period because Dr. Wadia's methodology is flawed. Respondent argues that Dr. Wadia's methodology is unreliable because: (1) It does not meet the standards set out in Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 593-594 (1993), and Kumho Tire Co. v. Carmichael, 526 U.S.

137, 149-150 (1999); (2) Dr. Wadia's interpretation of the qualified research criteria for the base period differs from the definition that petitioner used to identify the claim projects; and (3) Dr. Wadia is biased by MATRIC's relationship with Dow.

a. Reliability of Dr. Wadia's Methodology as Expert Testimony

Respondent argues that the Court should not rely on Dr. Wadia's opinion because it is unreliable under the standards set out in Daubert v. Merrell Dow Pharms., Inc., supra at 593-594, and Kumho Tire Co. v. Carmichael, supra at 149-150. Respondent argues that to evaluate the reliability of Dr. Wadia's methodology, the Court should consider the following factors: (1) Whether the methodology has been or can be tested; (2) whether the methodology has been published or subjected to peer review; (3) whether the methodology is subject to potential or known errors; and (4) whether the methodology is generally known and accepted within the relevant community. Daubert v. Merrell Dow Pharms., Inc., supra at 593-594.

Petitioner argues that respondent is merely reasserting the challenges he previously made to the admissibility of Dr. Wadia's testimony and recasting them as challenges to the reliability of his testimony. While we decided before trial that Dr. Wadia's testimony was admissible under rule 104(a) of the Federal Rules of Evidence, to the extent that the Daubert factors also pertain to

the weight that we should give to Dr. Wadia's testimony we consider them here.

However, the Daubert factors are not necessarily pertinent in all cases, and their relevance depends upon the nature of ths issue, the expert's particular expertise, and the subject of his testimony. Kumho Tire Co. v. Carmichael, supra at 150. Dr. Wadia's testimony is helpful because of his specialized knowledge of UCC's production processes and of how research and experimentation is conducted from a scientific point of view. Because of his years of experience working for UCC, Dr. Wadia is familiar with the way UCC conducted plant-based experimentation during the base period. While UCC's production processes rely on many principles of the physical sciences and the Court is assisted by Dr. Wadia's view of research and experimentation from a scientist's perspective, Dr. Wadia's task in identifying activities that satisfy the qualified research criteria is not itself founded on principles of science. See Tuf Racing Prods., Inc. v. Am. Suzuki Motor Corp., 223 F.3d 585, 591 (7th Cir. 2000) (stating that "The principle of Daubert is merely that if an expert witness is to offer an opinion based on science, it must be real science, not junk science", and finding that Daubert is not applicable when the expert does not "purport to be doing science"). Accordingly, an analysis of the Daubert factors is of limited value.

i. Whether the Methodology Can Be Tested

Respondent argues that Dr. Wadia's methodology cannot be tested because Dr. Wadia's opinions are merely general, conclusory statements. Respondent argues that Dr. Wadia's descriptions of the runs are sparse and do not refer to any specific facts to support his conclusions. Furthermore, respondent argues that Dr. Wadia does not set forth any reasons for his conclusion that the projects that he did not list as identified runs did not satisfy the qualified research criteria. Respondent contrasts Dr. Wadia's practices with those of Ms. Toivonen, who maintained workpapers that documented her decisions for the purpose of permitting her results to be checked and verified.

We disagree that Dr. Wadia's methodology cannot be tested. While it would be difficult for another person to duplicate Dr. Wadia's efforts exactly, Dr. Wadia's method of reviewing documents, interviewing people familiar with events that occurred during the base period, and discussing each project with the MATRIC team is a relatively simple methodology that could be repeated by others. Furthermore, because each project that Dr. Wadia included as an identified run is essentially a concession by petitioner, we do not find that Dr. Wadia's failure to explain in greater detail why those projects satisfy the qualified research criteria detracts from his reliability. While it would have been more helpful to the Court if Dr. Wadia had explained why he rejected the projects that

he did not list as identified runs, given petitioner's concession of runs 807 through 820 (discussed below), we have sufficient information to conclude that runs 1 through 820 include all of the additional qualified research activities that occurred during the base period.

ii. Whether the Methodology Is Known or Accepted in the Community, Has Been Published, or Has Been Subjected to Peer Review

Respondent also argues that Dr. Wadia's methodology was not known or accepted in the community, was not published, and was not subject to peer review. Respondent argues that there are no accepted standards or controls for applying Dr. Wadia's methodology.

Petitioner responds that this factor is simply not applicable to Dr. Wadia's task, and we agree. We find it highly unlikely that there are any published methodologies in the scientific world on how to identify research or experimentation performed by a company for a given set of years, but clearly Congress did not intend for the research credit to be unattainable because of the absence of a peer-reviewed methodology.

iii. Whether the Methodology Is Subject to Known Rate of Error

Respondent further argues that there is no known rate of error in applying Dr. Wadia's methodology. However, respondent believes that Dr. Wadia's methodology was subject to errors as evidenced by

(1) Dr. Wadia's supplemental report, which added 29 identified runs that Dr. Wadia did not include in his original report, and (2) petitioner's concession of runs 807 through 820. Respondent points out that petitioner's concession doubled the number of runs associated with the Triton Assets from 2 to 4. As evidence of Dr. Wadia's lack of thoroughness, respondent argues that Dr. Wadia should not have missed the wastewater activity test (run 809), which is described as a "plant test" in its supporting documentation. Respondent also argues that Dr. Wadia erroneously treated the forced draft burner tests (runs 95 and 96) as occurring in 1985 instead of 1984 in his original expert report; erroneously treated natural draft burner tests on furnaces 10 and 12 as occurring in 1985 instead of 1984 or earlier; and incorrectly determined the duration of the forced draft burner tests, the natural draft burner tests on furnaces 10 and 12, and the natural draft burner tests (runs 1 through 11) on furnace 9.

Petitioner argues that Dr. Wadia's methodology is not the type of methodology that can be assigned a known rate of error because it is not the type of research that is generally the subject of statistical studies. We agree that whether a project or test satisfies the qualified research criteria from a scientific point of view is not a question that can be scientifically verified to a certainty. While Dr. Wadia's experience as a scientist was central to his task, reasonable scientists could disagree as to whether

some projects satisfy the qualified research criteria; and it is the duty of the Court to determine whether any particular project does in fact satisfy section 41(d). We find that it is unlikely that any method of identifying qualified research has been assigned a rate of error, but Congress clearly intended for some taxpayers to be eligible for the research credit. Accordingly, the absence of a known rate of error does not affect the weight we will give to Dr. Wadia's testimony.

Furthermore, we do not find that Dr. Wadia's "failure" to include the wastewater activity test on his list of identified runs indicates that Dr. Wadia was not thorough because we find that the wastewater activity was not qualified research. While referred to as a "plant test" in the supporting documentation, this project did not involve any experimentation but was merely odor testing. Even if UCC did form a hypothesis before conducting this activity, there is no evidence that UCC performed any analysis of the results.

Regarding Dr. Wadia's mistake of concluding that the forced draft burner tests occurred in 1985 instead of 1984, we find that this mistake was immaterial and it was sufficient that Dr. Wadia corrected the mistake in his supplemental expert report. Furthermore, respondent's arguments regarding natural draft burner tests on furnaces 10 and 12 are contrary to our findings of fact–-we find that the tests on those furnaces occurred before the base period and Dr. Wadia correctly excluded them from his list of

identified runs. We also find that Dr. Wadia's determination of the duration of the forced draft burner tests and the tests on furnace 9 during the natural draft burner tests do not understate the duration of those runs.

While we do not accept Dr. Wadia's testimony as an opinion as to which activities satisfy section 41(d), we find that he interpreted the qualified research criteria using his knowledge of scientific research and experimentation, and we find his identification of runs that satisfy the qualified research criteria from a scientific point of view to be helpful to the Court. We find that any errors in Dr. Wadia's methodology have been cured by petitioner's concession of runs 807 through 820, which we believe constitute the activities that may not constitute qualified research but that bear enough marks of qualified research that they must be considered to ensure that petitioner has not omitted any qualified research activities from its base period calculations. Considering that (1) petitioner conceded the Nalco inhibitor test and the wastewater activity, which we find do not constitute qualified research, and (2) respondent has not identified any projects that petitioner failed to include that do constitute qualified research, we find it unlikely that there are other projects that do satisfy the qualified research criteria that petitioner has failed to identify and concede.

b. Petitioner's Definition of "Qualified Research"

Respondent argues that even if he has not identified other activities that should have been included in petitioner's base period calculation, the burden is on petitioner to prove that it has included in its base period calculations all of the activities that are similar to the claim projects, and that petitioner has not satisfied that burden. Respondent argues that petitioner cannot use Dr. Wadia's expert testimony to prove that it identified all of the activities that occurred during the base period that are similar to the claim projects because Dr. Wadia did not use the claim projects as models when applying the qualified research criteria or give any consideration to whether he identified all activities that were similar to the claim projects when carrying out his task. Furthermore, respondent argues that Dr. Wadia's interpretation of the qualified research criteria was narrower than petitioner's credit year position.

As evidence, respondent again points to the Nalco inhibitor antifouling test, which involved an activity that was very similar to petitioner's largest claim project, the UOP GA-155 project. Had Dr. Wadia been charged with identifying all projects that were similar to the claim projects, respondent argues that Dr. Wadia would have included the Nalco inhibitor antifouling test on his original list of identified runs.

Respondent also argues that Dr. Wadia did not rely on the "rule of three" when determining whether activities satisfied the qualified research criteria even though petitioner relied upon the rule of three for including some of the UCAT-J runs as qualified research. Accordingly, respondent argues that Dr. Wadia may have excluded some activities from his list of identified runs even though the technology tested in those runs had been proven in only one or two successful runs.

Petitioner argues that it satisfied the consistency requirement because the qualified research criteria that Dr. Wadia relied upon mirror the requirements of section 41 and the regulations promulgated thereunder, and these were the same criteria that petitioner used for its credit year claims. Petitioner argues that using the same selection criteria for both the credit years and the base period indicates that it complied with the consistency requirement.

We agree that the Nalco inhibitor antifouling test closely resembles the UOP GA-155 project and that the fact that Dr. Wadia did not include the Nalco inhibitor antifouling test on his list of identified runs suggests that he interpreted the qualified research criteria more narrowly than petitioner interpreted the criteria when selecting the claim projects. However, as discussed above, we find that neither the UOP GA-155 project nor the Nalco inhibitor antifouling test was qualified research. We find that Dr. Wadia's

failure to include projects similar to those claim projects that fail the qualified research tests is not sufficient basis for denying petitioner an additional research credit. As petitioner correctly argues, the consistency requirement does not alter the definition of qualified research under section 41(d). Accordingly, petitioner's failure to adhere to section 41(d) when selecting some of the claim projects does not necessarily indicate that Dr. Wadia failed to identify all of the qualified research activities that occurred during the base period.

Furthermore, we find that the fact that Dr. Wadia did not rely on the rule of three does not detract from his reliability. The evidence indicates that the rule of three applied only to the PE production process during the credit years, not to the entire C&P division. Furthermore, we find that Dr. Wadia is qualified to determine whether UCC considered its technology to be experimental or commercial during the base period.

Respondent also argues that because Dr. Wadia kept no records of the projects that he rejected, there is no way to verify his conclusions or consider whether he was correct to reject those projects. Accordingly, respondent argues that Dr. Wadia's statement that he identified virtually all of the qualified research activities that occurred during the base period is a conclusory opinion that cannot be verified.

We agree that this is a flaw in Dr. Wadia's methodology. However, we find that petitioner's concession of runs 807 through 820 cures Dr. Wadia's failure to identify the group of base period projects that failed the qualified research criteria in Dr. Wadia's opinion but might have satisfied the Court's interpretation of section 41(d) because runs 807 through 820 constitute that group of projects. While we find it unnecessary to analyze all of the conceded runs in the light of petitioner's concession that they do satisfy section 41(d), the fact that the two runs that respondent specifically criticizes Dr. Wadia for missing do not satisfy the requirements of section 41(d) suggests that petitioner's concession of these runs sufficiently broadens petitioner's definition of "qualified research" for the base period so that it is at least as broad as, if not broader than, the Court's interpretation of section 41(d). Accordingly, under the reasoning in Cohan v. Commissioner, 39 F.2d 540, 543-544 (2d Cir. 1930), we accept petitioner's list of identified runs, including concessions, as a close approximation of all of the qualified research activities that occurred during the base period. It is highly unlikely that Dr. Wadia failed to include any projects that would materially alter petitioner's base period computations. Our view is supported by the 17 fact witnesses who testified they were not aware of any plant experiments that occurred during the base period that were not included on the list of identified runs except for the

experiments that petitioner subsequently conceded. While we agree with respondent that the memories of the fact witnesses may be faulty, we find that when taken together as a whole the evidence shows that petitioner has satisfied its duty to identify all of the activities that occurred during the base period that it was required to take into account in calculating its base amount.

While including all of the conceded runs may overstate petitioner's base amount, petitioner failed to provide the Court with any other way to ensure that it has identified all of the additional qualified research activities that occurred during the base period and must bear the consequences of its own inexactitude. See id.

c. Whether Dr. Wadia Is Biased

Respondent argues that Dr. Wadia's methodology is flawed because Dr. Wadia is biased by MATRIC's relationship with Dow and Dr. Wadia's reliance on petitioner's counsel to conduct document searches. Respondent argues that Dr. Wadia's failure to include the wastewater activity (run 809) on his list of identified runs is evidence of Dr. Wadia's bias.

As discussed above, we do not think that Dr. Wadia was mistaken in failing to include the wastewater activity on his list of identified runs. Respondent has failed to offer any other evidence that indicates that Dr. Wadia was biased or that his

expert testimony was compromised because of MATRIC's relationship with Dow.

IV. Claimed Costs

To be eligible for the research credit under section 41(a)(1), a taxpayer must incur QREs during the credit year. QREs are generally defined as the sum of the taxpayer's in-house research expenses and contract research expenses that are paid or incurred during the taxable year in carrying on the taxpayer's business. Sec. 41(b). Petitioner does not claim as QREs any contract research expenses and the parties do not dispute that the claimed costs were incurred during the taxable year in carrying on UCC's business.

In relevant part, section 41(b)(2)(A) defines in-house research expenses as:

> (i) any wages paid or incurred to an employee for qualified services performed by such employee, [and]
>
> (ii) any amount paid or incurred for supplies used in the conduct of qualified research * * *

Section 41(b)(2)(C) defines the term "supplies" as any tangible property other than:

> (i) land or improvements to land, and
>
> (ii) property of a character subject to the allowance for depreciation.

Supplies must be used in the conduct of qualified research for their costs to constitute QREs. Sec. 41(b)(2)(A)(ii). Amounts incurred for supplies or property used only indirectly for

qualified research or for general and administrative expenses are not QREs. Sec. 1.41-2(b)(1), Income Tax Regs.

Wages paid to an employee constitute QREs to the extent that they are paid or incurred for qualified services performed by the employee. Section 41(b)(2)(B) provides that the term "qualified services" means services consisting of:

> (i) engaging in qualified research, or
>
> (ii) engaging in the direct supervision or direct support of research activities which constitute qualified research.

Engaging in qualified research "means the actual conduct of qualified research (as in the case of a scientist conducting the laboratory experiments)." Sec. 1.41-2(c)(1), Income Tax Regs. Section 1.41-2(c)(2), Income Tax Regs., defines "direct supervision" as follows:

> (2) Direct supervision.--The term "direct supervision" as used in section 41(b)(2)(B) means the immediate supervision (first-line management) of qualified research (as in the case of a research scientist who directly supervises laboratory experiments, but who may not actually perform experiments). "Direct supervision" does not include supervision by a higher-level manager to whom first-line managers report, even if that manager is a qualified research scientist.

The regulations define "direct support" as services in the direct support of either (1) persons engaging in actual conduct of qualified research or (2) persons directly supervising persons engaged in actual conduct of qualified research. Sec. 1.41-2(c)(3), Income Tax Regs.

As discussed above, the Amoco anticoking research activities and the UCAT-J research activities constitute "qualified research". However, we find that the production activities associated with both projects are not part of the experimental process business component and do not satisfy the process of experimentation test. Production activities are associated with the separate, nonexperimental, product business components. Accordingly, only the costs of supplies and wages that relate to UCC's research activities, not production activities, may be QREs.

Petitioner argues that the costs of all supplies and wages that were incurred during the Amoco anticoking and UCAT-J projects are QREs because the projects could not have occurred without the supplies, particularly the raw materials, that were used to make the products or without the employees who were operating the plant, and the costs of these supplies and wages are not otherwise excluded from the definition of QREs in section 41(b).

We agree that the Amoco anticoking and UCAT-J projects could not have occurred if UCC had not purchased the raw materials it used in its production process, raw materials that UCC previously treated as inventory and deducted as costs of goods sold. However, this does not make the costs of these raw materials QREs. The definition of supplies QREs includes only amounts "paid or incurred for supplies used in the conduct of qualified research". Sec. 41(b)(2)(A)(ii) (emphasis added). Petitioner now seeks to include

as QREs amounts incurred during the production process upon which the qualified research was conducted, not during the conduct of qualified research itself. These costs are, at best, indirect research costs excluded from the definition of QREs under section 1.41-2(b)(2), Income Tax Regs.

Petitioner argues that section 41 does not further define the phrase "used in the conduct of" and the regulations provide only that supplies are "used in the conduct of qualified research if they are used the performance of qualified services". Sec. 1.41-2(b)(1), Income Tax Regs. Accordingly, petitioner argues that the phrase "used in the conduct of" should be interpreted in its ordinary, everyday sense, citing Commissioner v. Brown, 380 U.S. 563, 571 (1965).

We find that petitioner's argument fails to recognize the precise definition of "qualified research" found in section 41(d). Section 41(d)(2)(C) provides that when a taxpayer seeks a research credit related to its production process, the production process must be divided into two business components, one that relates to the process and another that relates to the product. This indicates that Congress intended to allow taxpayers research credits for research performed to improve their production processes, but Congress did not intend for all of the activities that were associated with the production process to be eligible for the research credit if the taxpayer was performing research only

with respect to the process, not the product. See sec. 1.41-4(b)(1), Income Tax Regs. Here, the disputed supplies were raw materials used in the commercial production and sale of finished products. They were used to make products for sale, not for experimentation.

The limited congressional intent is also expressed in the shrinking-back rule, which permits taxpayers to divide a business component into activities that do and do not satisfy the qualified research tests when a project would otherwise be disqualified when considered in its entirety. See sec. 1.41-4(b)(2), Income Tax Regs. Taxpayers may not circumvent the narrow definition of qualified research that Congress intended by including as QREs costs of a project that are not incurred primarily as a result of the qualified research activities. Raw materials used to make finished goods that would have been purchased regardless of whether a taxpayer was engaged in qualified research are not "used in the conduct of qualified research". See sec. 41(b)(2)(A)(ii).

Similarly, the costs of wages constitute QREs only if they are paid for services consisting of engaging in or supervising qualified research. Sec. 41(b)(2)(B). Services performed by employees for activities that would occur regardless of whether the taxpayer was engaged in qualified research are not qualified services. See sec. 41(b)(2)(A)(i).

When section 41(d)(2)(C) applies and the relevant business component is the process, and production of the product alone would not constitute qualified research, we find that the costs of supplies that would be purchased and wages attributable to services that would have been provided regardless of whether research was being conducted are costs associated with the product business component and are not incurred in the conduct of qualified research. However, additional supplies costs incurred because qualified research is being performed on the process or wages attributable to services that would not normally have been provided are attributable to the process business component and are allowable as QREs if they otherwise satisfy section 41(b).

Petitioner argues that Fudim v. Commissioner, T.C. Memo. 1994-235, requires a different result because in that case the Court treated as QREs the costs of materials that the taxpayer used to make plastic objects as part of his research on a process known as "rapid modeling". These costs included the cost of the photopolymers that were fabricated into the plastic objects.

However, in Fudim the taxpayer's rapid modeling process was not a "plant process * * * for commercial production" of a product that he himself fabricated and sold within the meaning of section 41(d)(2)(C). The Court found that the taxpayer was not in the business of producing the plastic objects for sale but "derived only a minimal amount of income on the models he made during those

years." Accordingly, there was no need to allocate costs between the process business component and a product business component. Id. Unlike the supplies UCC used in its claim projects, which would have been purchased for production even if no research had been performed, the supplies the taxpayer in Fudim purchased were "devoted to research." Id. (emphasis added). For these reasons, we find Fudim to be distinguishable.

Petitioner also argues that Lockheed Martin Corp. v. United States, 49 Fed. Cl. 241 (2001), supports its position because it implicitly holds that a "component part" of a product to be delivered to a customer can constitute a "supply" within the meaning of section 41(b). In that case, the court rejected the Government's motion for summary judgment that component parts used to make Supersonic Low Altitude Target (SLAT) devices could not be "supplies". Id. at 247.

We disagree that Lockheed Martin supports petitioner's argument. In that case the court explicitly declined to consider whether the component parts were used in the conduct of qualified research. Id. at 245-246. Furthermore, Lockheed Martin is distinguishable from the case before us because in that case the relevant business component was the SLAT device, not the process used to make the SLAT devices.

Petitioner also cites a Canadian tax case, Consoltex Inc. v. R, [1997] 2 C.T.C. 2846, in support of its position. In Consoltex,

the court held that the cost of yarn used by a textile producer during research conducted to develop improved textile products was eligible for a scientific research and experimental development credit. Consoltex addressed a provision of Canadian law, not the section 41 research credit. In any event, Consoltex is distinguishable because, as in Lockheed Martin, the research conducted related to an experimental product and not the process of producing the product.

Petitioner argues that at many times during the conduct of the claim projects UCC did not know whether the product produced would meet customer specifications. However, this does not indicate that UCC was conducting qualified research on its products. To the contrary, petitioner has argued that for purposes of determining whether the claim projects constitute qualified research we should focus our analysis on the process, not the product. In any event, the evidence clearly indicates that to the extent that UCC was conducting research on its end products its activities would be excluded from the definition of qualified research under section 41(d)(4)(A) as research after commercial production because all of the products UCC produced during the claim projects satisfied UCC's functional and economic requirements. The fact that UCC occasionally produced off-specification products does not change the fact that UCC had already commercialized those products.

Even if we were to include production activities as part of the relevant business components, the production costs petitioner claims are QREs would not be eligible for the research credit under Mayrath v. Commissioner, 41 T.C. at 590, which limits deductions under section 174 "to those expenditures of an investigative nature expended in developing the concept of a model or product." Section 41(d)(1)(A) incorporates section 174 into the definition of qualified research. Petitioner cannot avoid the restrictions of section 174 by arguing that section 174 is relevant only for determining whether activities constitute qualified research and has no bearing on whether the costs of those activities may be QREs. See Norwest Corp. & Subs. v. Commissioner, 110 T.C. at 491; H. Conf. Rept. 99-841 (Vol. II), supra at II-71, 1986-3 C.B. (Vol. 4) at 71 ("the conference agreement limits research expenditures eligible for the incremental credit to 'research or experimental expenditures' eligible for expensing under section 174.").

Furthermore, the fact that petitioner first sought the research credit for the claimed costs in its petition is strong evidence that petitioner did not view these costs as research costs and that UCC would have incurred these costs without the incentive of the research credit. Production costs that UCC would have incurred without the incentive of the research credit

are not the types of costs that Congress sought to target when it enacted the research credit.

Petitioner bears the burden of proving its entitlement to the additional research credits claimed in the petition. See Rule 142; New Colonial Ice Co v. Helvering, 292 U.S. 435, 440 (1934); Norwest Corp. & Subs. v. Commissioner, supra at 488-489 n.34; Eustace v. Commissioner, T.C. Memo. 2001-66.

Petitioner's claimed costs for supplies for both the Amoco anticoking and UCAT-J projects include only costs of production. Instead of calculating the cost of supplies that UCC used specifically to perform experiments during production or analyze data, petitioner's calculations are founded on the assumption that UCC did not increase its supplies costs during the claim projects above its normal raw materials costs used in its plant cost system to compute cost of goods sold. It does not appear that petitioner had any additional supplies QREs to claim because petitioner claims as QREs only the raw material costs of the finished products and not any additional supplies. This indicates that petitioner has not allocated its claimed QREs between the experimental process business components and the nonexperimental product business components of those projects. Furthermore, petitioner did not distinguish between activities that constitute elements of a process of experimentation and ordinary production activities. We find that the claimed

supplies costs are ordinary production costs that were properly included in inventory and petitioner has not satisfied its burden of proving that the costs it claims as supplies QREs were used in the conduct of qualified research as required by section 41(b)(2)(A)(ii). Petitioner has had ample opportunity to establish that it incurred additional supply QREs for the claim projects and has not carried its burden. Accordingly, we find that petitioner is not entitled to claim any additional supply QREs for the claim projects, and we need not address respondent's remaining arguments that relate to the costs of these projects.[52]

The research credits claimed on petitioner's original returns and allowed by respondent included the wages of UCC's R&D scientists and engineers at its technical centers. Petitioner now seeks to treat as additional QREs amounts paid to operators at Taft and Star for the Amoco anticoking and UCAT-J projects, respectively.

For the Amoco anticoking project, petitioner treated as wage QREs the wages paid to Mr. Hyde, Mr. Tregre, and Mr. Gorenflo

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[52]Respondent also argues that: Petitioner should not have included the costs of utilities in its supplies costs because utilities are generally excluded from the definition of qualified research unless they are extraordinary, and they were not extraordinary for the claim projects, see sec. 1.41-2(b)(1) and (2), Income Tax Regs.; petitioner's claimed supplies costs are unreasonable and are therefore excluded under secs. 174 and 41(d)(1)(A); petitioner has failed to substantiate its supplies costs; and Ms. Hinojosa erred in her allocation of one-seventeenth of Taft's ethylene supply costs to the Amoco anticoking project.

according to the number of hours each spent working on the project. Mr. Hyde and Mr. Tregre both credibly testified that they spent a combined total of 50 hours working on the Amoco anticoking project. We find that the services that Mr. Hyde and Mr. Tregre provided in connection with the Amoco anticoking project, including planning the tests, participating in the pretreatments, and sending the data to the technical center to be analyzed, constitute qualified services. While respondent argues that petitioner has not substantiated its claimed QREs, we find that the testimonies of Mr. Hyde, Mr. Tregre, and Ms. Hinojosa were credible and sufficiently substantiated the wages paid to these employees. We find that petitioner has satisfied its burden and may treat as wage QREs $835 and $210 for 1994 and 1995, respectively.[53] However, Mr. Gorenflo did not testify as to how much time, if any, he spent on the Amoco anticoking project. Accordingly, petitioner has not satisfied its burden of proving that Mr. Gorenflo spent 2 hours engaged in qualified research with respect to the Amoco anticoking project in 1994 and may not claim his wages as QREs.

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[53]Mr. Hyde spent 35 and 10 hours working on the Amoco anticoking project in 1994 and 1995, respectively, and his wage rate was $21 per hour. Mr. Tregre spent 5 hours working on the Amoco anticoking project in 1994 and his wage rate was $20 per hour.

The parties agree as to the operation of sec. 280C(c) and any adjustments that may be required as a result of our decision. Accordingly, we do not discuss it here.

For the UCAT-J project, petitioner treated as additional QREs a percentage of all wages paid to Star plant personnel during 1994 and 1995 without determining which employees worked on the UCAT-J project or how many hours they dedicated to the project. Petitioner has not provided any evidence that shows how much time Star's plant employees actually spent on the UCAT-J project, and there is no way to determine whether petitioner's estimate is accurate. It appears that petitioner has already received a credit under section 41 for the wages of most of the employees who engaged in qualified research during the claim years--the R&D scientists and engineers. Accordingly, petitioner is not entitled to any additional QREs attributable to wages paid for the UCAT-J project.

V. Base Period QREs

A. Alleged Flaws in Ms. Toivonen's Costing Methodology

Petitioner claims that it incurred $135,112,912 of QREs during the base period on the basis of Ms. Toivonen's costing calculations of the runs identified by Dr. Wadia. Respondent argues that Ms. Toivonen's methodology is flawed for the same reasons respondent argues that Dr. Wadia's methodology is flawed because Ms. Toivonen failed to review or verify Dr. Wadia's determinations of the run durations and production quantities. However, as discussed above, we find that any flaws in Dr. Wadia's methodology have been cured by petitioner's concessions,

and accordingly Ms. Toivonen's reliance on Dr. Wadia was justified.

Respondent also argues that Ms. Toivonen's methodology is flawed because she relied on Ms. Hinojosa and other Dow employees to identify the lead PCDs and MASs relating to the products produced. However, respondent does not argue that Ms. Hinojosa or the other Dow employees were unqualified to identify the lead PCDs and MASs or that they performed their task poorly. To the contrary, we find that Ms. Hinojosa and other Dow employees were in the best position to correctly identify the lead PCDs and MASs because they were familiar with the products that UCC produced during the base period.

Respondent next argues that Ms. Toivonen was forced to use cost accounting information for similar products when the actual accounting information for a product was unavailable. Respondent believes that in some situations this caused Ms. Toivonen to omit supplies that were used in the production process. As an example, respondent points to the propyl dipropasol refining test (run 171), where Dr. Wadia listed sodium hydroxide as the catalyst but Ms. Toivonen calculated the cost of sodium propylate instead because it was listed on the PCD. Similarly, for the isophorone mids conversion test (run 173) and secondary refining system test (run 178), Dr. Wadia stated that certain materials

were used that Ms. Toivonen did not include in the cost of the runs because they were not listed on the PCDs.

Ms. Toivonen testified that in her expert opinion any discrepancies that may have occurred because she used accounting information that did not exactly match the products produced or Dr. Wadia's descriptions of the runs are immaterial. Regarding Ms. Toivonen's method of costing the propyl dipropasol refining test, we find that Ms. Toivonen did not understate the cost of the propyl dipropasol refining test because the cost of sodium propylate was most likely higher than the cost of sodium hydroxide.[54] While a more conservative calculation of the cost of the isophorone mids conversion and secondary refining system tests would have included the cost of materials that were used but omitted from the PCDs, we find that the omissions were immaterial given the small amount of materials that were used. We find Ms. Toivonen to be a credible expert witness, and in the absence of any evidence to the contrary we find that any errors in her conclusions that may have been caused by the accounting records she used are immaterial.

[54]Petitioner also argues that sodium propylate is the chemical product of reacting sodium hydroxide with proponal, and accordingly Ms. Toivonen's calculation did in fact include the cost of sodium hydroxide. However, given our finding, we need not decide whether it is appropriate to take judicial notice of this fact.

B. Alleged Errors in Ms. Toivonen's Calculations

Respondent also argues that Ms. Toivonen made errors in her report even when she used the correct documentation. As an example, respondent argues that Ms. Toivonen incorrectly calculated the cost of 90,000 pounds of acrolein for the acrolein refining system capacity test (run 128) instead of 1,800,000 pounds, the production quantity reported by Dr. Wadia. Ms. Toivonen testified that the discrepancy might be attributable to a unit of measure conversion, but she did not explain the discrepancy in her expert report and could not be certain when questioned about the discrepancy at trial.

In the absence of any clear explanation as to why she did not use the production quantity that Dr. Wadia provided, we find that Ms. Toivonen should have calculated the cost of producing 1,800,000 pounds of acrolein, which would increase the base period QREs by $283,654.80.[55] However, we do not agree with respondent that all of Ms. Toivonen's base period calculations should be disregarded because of this error and find it would be more appropriate to increase petitioner's QREs for 1987 by $283,654.80.

Respondent also argues that Ms. Toivonen lacked the technical expertise to calculate the cost of runs 807 through 820. As evidence, respondent points out that on cross-

[55]Ms. Toivonen calculated the supply cost per pound of acrolein as $0.16588.

examination Ms. Toivonen could not answer the question of whether the cost of naphtha was captured as one of the costs for the naphtha-sulfur injection test (run 807). Ms. Toivonen believes that the cost of the naphtha may have been captured on secondary PCDs, which she used to calculate the costs of materials listed on lead PCDs, but she could not be sure.

Respondent also argues that Ms. Toivonen incorrectly determined that the naphtha-sulfur injection test lasted for 35 days because other documents indicate that it lasted much longer than 35 days. As evidence, respondent points to two industrial chemicals division monthly reports, one for December 1985, dated January 13, 1986, and a second for July 1986, dated August 11, 1986. The report for December 1985 states that the test began on December 16, which is the date that Ms. Toivonen determined the test began. The report for July 1986 does not mention the test at all.

We do not think that the naphtha-sulfur injection test is evidence that Ms. Toivonen lacked the technical expertise to calculate the cost of runs 807 through 820. Ms. Toivonen captured the costs of the materials listed on the lead PCD for the product, and we find the lead PCD to be a reliable document to use to calculate the cost of producing a finished product. While, as discussed below, this test does highlight a different flaw in petitioner’s costing methodology because it includes only

the cost of ordinary production activities, we find that the fact that naphtha was not listed on the lead PCD suggests that its cost would not materially affect the cost of producing the product made in the naphtha-sulfur injection test.

Furthermore, the evidence that respondent argues indicates that the naphtha-sulfur injection test likely lasted much longer than 35 days does not so indicate. To the contrary, it indicates that it started on the date that Ms. Toivonen determined it started and had not been completed as of 3 days before the date that Ms. Toivonen determined that it ended.

Respondent also believes that Ms. Toivonen mistakenly failed to include the cost of refrigeration when costing the MMP refrigeration test (run 810). Section 1.41-2(b), Income Tax Regs., provides that general and administrative expenses do not qualify as QREs, and section 1.41-2(b)(2)(i)(1), Income Tax Regs., provides that utilities are generally treated as general and administrative expenses. However, section 1.41-2(b)(2)(ii), Income Tax Regs., provides that utilities may constitute QREs if they are extraordinary. Respondent argues that the cost of refrigeration in the MMP refrigeration test was extraordinary.

We find that refrigeration was not an extraordinary expenditure in the refrigeration capacity tests. In the first test, in which UCC evaluated transfer chiller control at negative 10 degrees Centigrade instead of negative 17 degrees Centigrade,

UCC actually used less refrigeration than it would have during the ordinary production of MMP. In the second test, in which UCC estimated the ambient heat gain of the day tanks and storage tanks, any refrigeration used was not above the normal amount that UCC would have used had it not been performing a test. Accordingly, we do not find the cost of refrigeration to have been an extraordinary expenditure during either of these tests.

C. Documents Ms. Toivonen Relied Upon

Respondent argues that Ms. Toivonen's methodology is flawed because Ms. Toivonen relied on petitioner's counsel to provide her with the accounting records related to runs 807 through 820 instead of conducting an independent search of all of the documents in the record. Furthermore, respondent argues that Ms. Toivonen looked only at accounting records to identify costs instead of identifying technical documents to see whether they provided additional information as to the duration or production quantity of the runs.

We find that the fact that Ms. Toivonen did not personally find the necessary accounting records she needed to cost runs 807 through 820 is irrelevant. There has been no suggestion, nor is there any evidence, that petitioner's attorneys were not competent to provide Ms. Toivonen with the documents she needed or that they withheld or tampered with any information. Given the large number of documents produced in this controversy, it

would have been impractical to require Ms. Toivonen to search through all of the documents in the record without the assistance of petitioner's counsel.

We also find that respondent's argument that Ms. Toivonen looked only at accounting records to calculate the cost of Runs 807 through 820 is inaccurate. Ms. Toivonen's supplemental expert report cites numerous technical documents and trial testimony to support her findings. For each run, Ms. Toivonen provided a reasonable explanation as to how she determined the duration and production quantity and included citations of technical documents and testimony where appropriate. While, as discussed above, respondent argues that Ms. Toivonen failed to review technical documents that contradict her findings regarding the duration of the naphtha-sulfur injection test, we find that the technical documents at issue are consistent with Ms. Toivonen's determinations for that test. Furthermore, because the refrigeration used in the MMP refrigeration tests was not extraordinary, there was no need for Ms. Toivonen to review additional documents to determine the cost of the refrigeration used. Accordingly, we find that Ms. Toivonen committed no error in relying upon the documents that she relied upon.

D. Consistency Requirement

Respondent argues that Ms. Toivonen's methodology for costing the identified runs was inconsistent with Ms. Hinojosa's

methodology for calculating the cost of the claim projects. Specifically, respondent disputes Ms. Toivonen's treatment of base case costs and wage costs.

1. In General

Respondent argues that the fact that petitioner claimed QREs of $43 million for the UOP GA-155 project indicates that petitioner failed to satisfy the consistency requirement because the largest base period project before the trial was costed as $5.1 million and the most QREs petitioner claims in 1 base period year are $33 million.

Respondent's argument is contrary to the purpose of the research credit. The research credit was designed to encourage taxpayers to increase their spending on qualified research. If the fact that a taxpayer incurred more QREs in a credit year than in the base period could be treated as dispositive that the taxpayer ran afoul of section 41(c)(4), this would thwart the purpose of the research credit.

Furthermore, we find that as a general matter, petitioner used the same methodology to calculate its credit year and base period QREs. In the opinions of Ms. Toivonen and Ms. Hinojosa, petitioner's accounting expert witnesses, the costing methodology Ms. Toivonen applied in calculating UCC's base period costs is consistent with Ms. Hinojosa's methodology. In arriving at this conclusion, each expert witness reviewed the methodology used by

the other. We find both expert witnesses to be credible on this matter and find that Ms. Toivonen's costing methodology was generally consistent with Ms. Hinojosa's costing methodology.

2. Base Case Costs

Respondent argues that petitioner's treatment of base case costs for the base period differs from its treatment of base case costs for the credit years. Respondent argues that for the Amoco anticoking project petitioner treated the cost of testing the untreated cracking sets as QREs but for the Nalco 5211 test (run 15) petitioner did not treat the cost of the base case runs as QREs. Respondent argues that both the Amoco anticoking project and the Nalco 5211 test used base cases and that petitioner should have treated both base cases the same.

We agree that it is possible that UCC conducted some qualified research before the start date petitioner determined for the Nalco 5211 test. However, as discussed above, we find that none of the supply costs that petitioner claimed with respect to the Amoco anticoking project constituted QREs. Similarly, we find that it would be inappropriate to treat the costs of raw materials that were used during the base case runs as QREs. While we allowed petitioner to treat $1,045 that UCC paid to two of its employees as wage QREs, this was less than one-tenth of 1 percent of the total QREs that petitioner claimed for the Amoco anticoking project. Accordingly, even if

petitioner improperly omitted wages paid to UCC plant employees to conduct qualified research before the date on which petitioner believes the Nalco 5211 test began, given petitioner's expansive reading of section 41(b) we find it highly unlikely that petitioner's calculation of the Nalco 5211 test understates the amount of QREs that were actually incurred. Accordingly, under the principles provided in Cohan v. Commissioner, 39 F.2d at 543-544, we find it more appropriate to accept petitioner's calculation of the Nalco 5211 test than to reject petitioner's efforts as a whole.

3. Wage Costs

Respondent next argues that Ms. Toivonen's method of calculating wage costs was inconsistent with the method Ms. Hinojosa used for the credit years, specifically the wage costs for the UCAT-J project. Ms. Hinojosa calculated the wage costs for the UCAT-J project by multiplying the total wages incurred for all Star employees by the ratio of UCAT-J production pounds to total production pounds in each of the credit years. Respondent argues that when calculating the wages incurred at Star for the base period, Ms. Toivonen inconsistently excluded a number of groups of personnel that were included in the credit year wage costs.

As discussed above, we find that none of the costs that petitioner claims as QREs with respect to the UCAT-J project

constitute QREs. Ms. Hinojosa determined that the amount of time spent by plant operators and other support staff during the UCAT-J runs was not significantly different when compared to normal production runs. This indicates that the employees whose wages Ms. Hinojosa calculated were not involved in the conduct of qualified research but were engaged in ordinary production activities. Even if those employees were involved in the conduct of qualified research, petitioner has offered no way of distinguishing the wages UCC it paid for its employees to engage in qualified research and to engage in ordinary production activities. Accordingly, petitioner did not violate section 41(c)(4) by excluding similar costs from its base period calculations.

E. Whether Ms. Toivonen Calculated the Cost of "Qualified Research" Activities

We find Ms. Toivonen's methodology to be flawed for the same reason that Ms. Hinojosa's methodology is flawed. In calculating the cost of the identified runs, Ms. Toivonen identified only ordinary production costs, not the costs of performing research.

The naphtha-sulfur injection test (run 807) highlights the flaw in petitioner's costing methodology that we discussed with regard to the claim projects. Ms. Toivonen calculated the cost of the naphtha-sulfur injection test as being the cost of producing ethylene, which is not an experimental product. However, if the naphtha-sulfur injection test constitutes

qualified research,[56] the activities that constitute process of experimentation would be limited to the planning of the test, injecting naphtha into the process stream, testing the results, and analyzing the results. The ordinary production activities that would occur during the production of ethylene regardless of whether an experiment was being conducted would fail the process of experimentation test, although most likely naphtha would be considered a supply used in the experiment. However, in costing the naphtha-sulfur injecting test, Ms. Toivonen included all of the ordinary production costs and excluded the cost of naphtha.

Ms. Toivonen similarly calculated the cost of all of the other identified runs as if they were ordinary production runs. Ms. Toivonen did not calculate the cost of any additional supplies that may have been purchased for the tests or calculate the wages paid to any specific plant employees who worked on the projects.

However, we find Ms. Toivonen's error to be harmless because it causes petitioner to overestimate its base amount, thereby reducing the research credit. Ms. Toivonen concluded that the total cost of all of the identified runs was $135,112,912. Because petitioner has provided us with no way to divide these costs between costs incurred in the conduct of qualified research and costs incurred as ordinary production costs, we shall treat

[56]We accept petitioner's concession that this run constitutes qualified research.

the entire amount as additional base period QREs, adjusted according to our findings.[57]

VI. Conclusion

We find that petitioner has established that it incurred additional wage QREs of $835 and $210 for 1994 and 1995, respectively, but no additional supplies QREs for the claim projects. Furthermore, we accept petitioner's calculations for the base period, adjusted according to our findings, as UCC's additional base period QREs. We shall instruct the parties to resolve any issues regarding the remaining credit year projects in a manner consistent with this opinion.

On the basis of the foregoing,

An appropriate order will be issued.

[57]We find that Ms. Toivonen improperly calculated the cost of the acrolein refining system capacity test.